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LIFE CYCLE ANALYSIS FOR A TECHNICAL, ENVIRONMENTAL AND ECONOMIC COMPARISON BETWEEN CORN AND SHALE GAS ETHANOL

A Thesis

by

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MASTER OF SCIENCE

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ABSTRACT

Biogenic ethanol from corn has proven effective as an oxygenate that improves gasoline engine performance. However, the US Renewable Fuel Portfolio legislation was written before shale gas became a huge technically recoverable resource in the U.S. This work investigates tapping this large methane resource as an alternative to biogenic ethanol. Recent technological advances have enabled inexpensive production of natural gas from shale that could be used for ethanol production instead of corn. This research compares these two options from several perspectives.

Ethanol from corn is controversial because corn is a fundamental source for both human ingestion and as animal feed. As such, the ultimate objective has been to develop technologies for cellulosic ethanol produced from the plant matter instead of the fruit from the plant. However, so far these technologies result in a much more expensive biofuel. Without cost-effective cellulosic ethanol, the amount of ethanol production is limited. The abundance of natural gas from shale could offer an alternative feedstock for ethanol production. Recent drops in natural gas price only improve the competitiveness of ethanol from natural gas over biofuels.

In the current work, we made a comparison between two synthesis routes for fuel ethanol. The first route is the process chain using corn as the feedstock. The second is an alternative processing route using shale gas as the feedstock. The method applied is a life cycle comparison considering each of the following four environmental elements: water,

atmosphere, land, and energy. While there are important impacts related to the interaction of these elements, this research will mainly focus on each element in isolation.

The comparison elucidates how shale gas could indeed be competitive to corn as feedstock for ethanol production. Moreover, we provide valuable arguments and tools for political discussions and decision making that could be useful for future policy development.

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NOMENCLATURE

CH4	Methane
CO	Carbon Monoxide
CO2	Carbon Dioxide
DDGS	Dried Distillers Grains with Soluble
DFSG	Domestic Fuel Solution Group
EPA	Environmental Protection Agency
GHG	Green House Gases
GWP	Global Warming Potential
LCA	Life Cycle Analysis
ROI	Return on Investment
Syngas	Synthesis Gas

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CHAPTER I

INTRODUCTION

Chapter I presents an introduction to the topic of this thesis. Since the topic is very extensive and has different technical aspects, the reader should understand the general scope of the project and the thesis direction after reading this chapter.

Background

This section begins with some general comments in the literature that are related to the overall thesis subject. Then a second section explains what is meant by Life Cycle Analysis (LCA). A final section describes processes found in the literature for making ethanol.

General comments

(Johnson, 2008) claimed that biofuel is a viable partial solution for global environmental problems because its carbon footprint was believed to be smaller and because of its apparent independence from fossil fuels. Today, taking into account what is implicated in its production and transformation processes, (Brahic, 2007), and (Mckenna, 2007) shed doubt on the value of biofuels. (Brahic, 2007) lists the use of fertilizers, pesticides, and other chemicals needed to implement a mass-productive grain as some of the impacts to be considered. (Mckenna, 2007) considered the high amounts of water used in the grain growth and its pollution and depletion, the energy requirements of the shipping and distribution together with the process demand itself, and the atmosphere pollution caused by machinery in the fields and in the plants. Following this same concerns are (Pimentel & Patzek, 2005) who came to the conclusion that

ethanol from corn needs 29% more energy than what it is able to produce, this two writers generated a big controversy around this topic with their concerns on ethanol production not meeting the net energy balance.

Specifically, (Ettie, 2006; Fargione, Hill, Tilman, polasky, & Hawthorn, 2008; Searchinger et al., 2008) reevaluated the viability of corn-based ethanol produced in the United States. Their work included investigation of many industrial services and utilities required through the harvest and synthesis processes that involve direct or indirect fossil fuel consumption. They show that many issues can be cited to enforce this concern both from an energy balance perspective the efficiency of this type of conversion and considering the use of natural resources such as arable land and fresh water.

The viability of ethanol production from natural gas must also be examined. For example, (Stevens, 2012) indicates environmental impacts from shale gas extraction has such as leaking of greenhouse gases, depletion of fresh water supplies, and pollution from compounds used for hydraulic fracturing and that these threats are deepened due to the variable conditions from one extraction site to another.

Life cycle analysis

The above observations show the need for a detailed analysis to compare the current biofuel implementation with ethanol production from natural gas, in particular, natural gas produced from shale. Life Cycle Analysis (LCA) provides a convenient mechanism for such a comparison.

(Horne, Grant, & Verghese, 2009) state that "The LCA comprises a systematic evaluation of environmental impacts arising from the provision of a product or service." This evaluation can represent a first step to produce real evidence where intuition is not enough to make a decision. This methodology is commonly used to compare environmental impacts of alternative paths for a process.

The life cycle analysis of the biogenic and fossil ethanol, which is how one could summarize the inclusion of all the mentioned items in a study of environmental impact, can be carried out with different scope depths (Powers, Dominguez-Faus, & Alvarez, 2010). But regardless of how meticulous the account of the process is, it has become clear that the advantage initially posed by this grain has to be reevaluated (Searchinger et al., 2008).

Processes for making ethanol

Following are processes found in the literature for making ethanol. First, the reader can find the known processes for making ethanol from corn. Second, the ways to make ethanol from natural gas.

Ethanol from corn process

Ethanol from corn has two main, and well-known processes. The first is called wet mill and the second process is called dry grind. (Wood, 2014) indicated that 88% of the ethanol production in the U.S is through the dry grind process.

The conversion process of cellulose into ethanol has two routes, enzymatic or thermochemical. Examples of enzymatic conversion are sugars, enzymes, and microorganisms. Thermochemical can be held through heating or gasification process. We should consider that ethanol from corn grains or from cellulosic sources represent the same type of ethanol as a product, although the price is higher for cellulosic conversion process. (Clean Fuels Development Coalition, 2010)

The first process, receives its name wet mill because the main stage needs the corn grains to be submerged in water to facilitate breaking the components. The idea to break the fiber, germ, and starch from corn grains is to use the different byproducts. (Mosier & Ileleji, 2012) **Figure 1** shows a detailed diagram of the wet mill process steps.

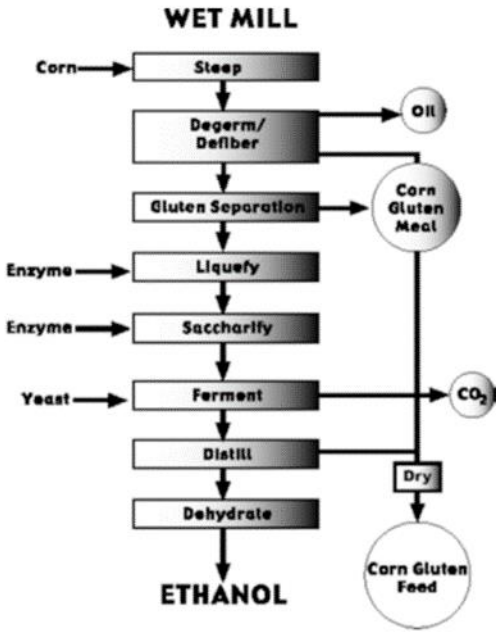

Figure 1: Wet mill process (Bothast & Schlicher, 2005)

As described by (Bothast & Schlicher, 2005) the second process is the dry grind, where the whole grain is used, and at the end of the process the different components are separated. In the dry grind process, the clean corn is ground and mixed with water to become what is called mash. Enzymes are added while cooking in order to convert the starch into sugar. Fermentation, lets the glucose converts into ethanol by adding yeast. Then the purification process occurs by distillation to purify ethanol to a fuel type. The last step is dried distillery grains separation and drying which is used as animal food. **Figure 2** shows the dry grind process.

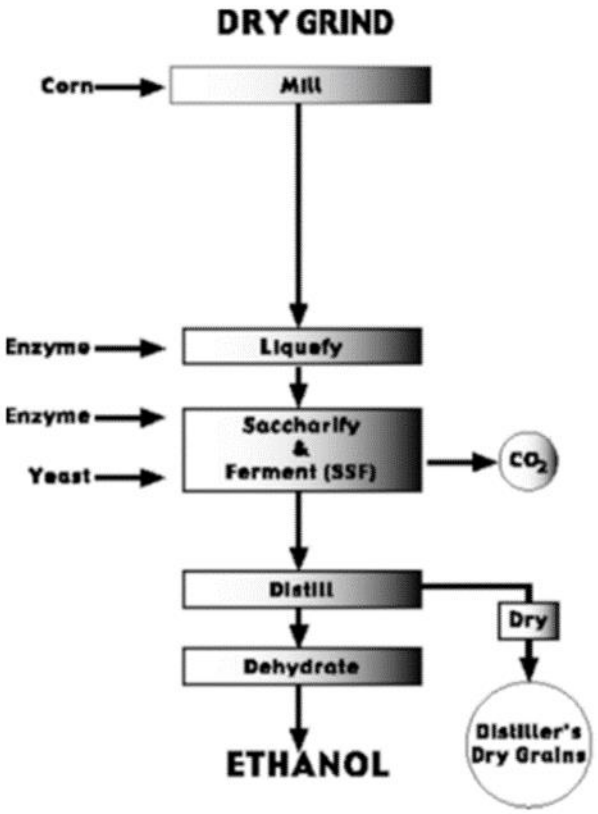

Figure 2: Dry grind process (Bothast & Schlicher, 2005)

The wet mill process is more expensive than the dry grind, since the grain needs to be separated into different components. The advantage to this process is that it can produce more high-value products, and it is seen as a more technical process. Nonetheless, the recent ethanol industry growth in the U.S. is with dry grind plants due to lower cost per gallon.

There are several methods to characterize energetic profit for a given process (Patterson, 1996; Phylipsen, 2010). What gives more explicit information is the comparison between any new energy sources with a fossil fuel, gasoline for example. The energy expended obtaining, distributing and transforming the ethanol from the shale gas or from the corn, depends largely on the scope´s depth chosen.

The life cycle analysis of the biogenic and fossil ethanol, which is how one could summarize the inclusion of all the mentioned items in a study of environmental impact, can be carried out with different scope depths (Powers et al., 2010). But regardless of how meticulous the account of the process is, it has become clear that the advantage initially posed by this grain has to be reevaluated (Searchinger et al., 2008). Taking for instance, the net amount of energy required to produce and ship raw matter and product in the ethanol industry, in order to compare it to the conversion of oil into gasoline, can portrait how insights in the direct and indirect costs imply important modifications of the relative efficiency determined for each product.

The biofuel industry has generated energetic comparisons for different crop-based ethanol. For the corn-based ethanol 1.36 BTUs are obtained for every BTU of fossil fuel applied in the process (Hofstrand, 2007), other studies (Hill, Nelson, Tilman, Polasky, & Tiffany, 2006)

showed a net energy balance of 1.25 energy units for every energy unit expend in its production. On the other side, we have the discussion from (Pimentel & Patzek, 2005) with a negative energy output of 29% in comparison with the previous authors with a positive output of 36% and 25% respectively. Regarding its variability, it is important to consider that better industrial methods (process integration, etc.) may increase this performance, but also may decrease due to poor corn yield. Illustrating this fact, a plant using corn stover as a fuel for heat processes and some electric generation can elevate its net energy balance up to 4.5.

The conversion process itself has to be mentioned as well, since this process also demands a high percentage of the energy used in the entire production chain. In **Figure 3** the whole process is depicted. Individually every sub-process has an iconic representation of the technology commonly applied. For each of them, one can find different types and amounts of energy usage.

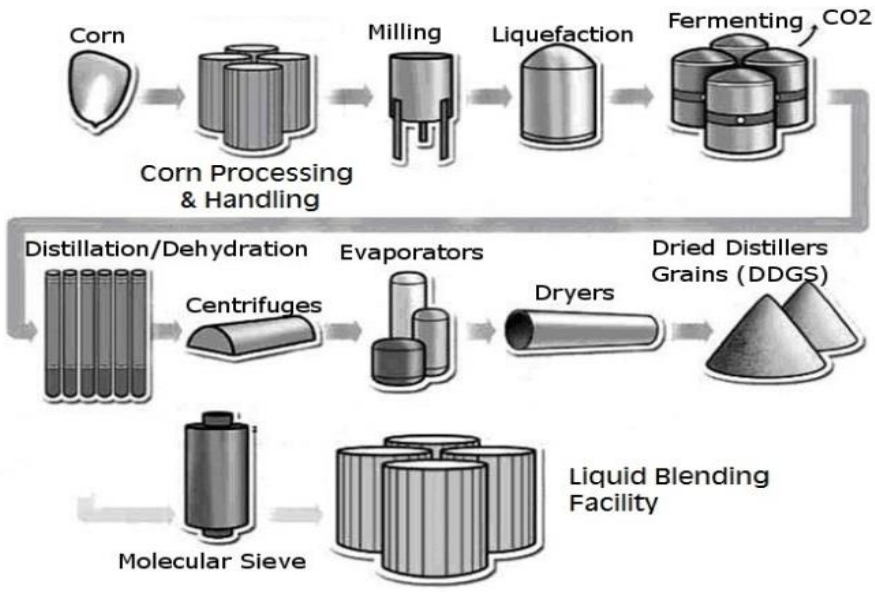

Figure 3: Corn-based process (RFA, 2014)

Ethanol from natural gas process

Converting natural gas into ethanol or any other liquid fuel, comprises the process shown in **Figure 4**. First step is reforming of natural gas to obtain a syngas (synthesis gas), then this gas undergoes a catalytic process to be converted into different chemicals and fuels, such as ethanol, methanol, methane, among others.

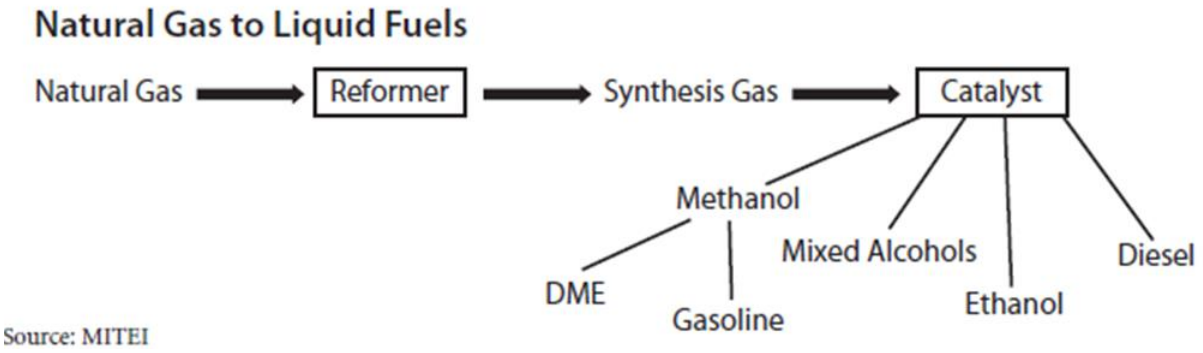

Figure 4: Natural gas to liquid fuels (Massachusetts Institute of Technology., 2010)

The above process, while well known, has not become commercial. The process of converting gas to liquids has been under development in the past years. The are several technological advances for this type of conversion. Some of the companies who have developed commercial technology for this purpose are Coskata with a biochemical pathway, Celanese with a catalytic and thermochemical pathway, and LanzaTech and Siemens with a biochemical pathway.

The researches carried out so far lead to the conclusion that the resources consumption, "the energy requirements for shale gas field development are higher than for conventional natural gas field development"(Tiffany, 2009).The diversity in the well conditions makes an equally

diverse net energy balance distribution. Consequently, individual assessment for each shale gas formation is generally needed in order to establish its energetic convenience. For Europe, for instance, shale gas could only have a small contribution to its energetic demand. Comparing it with strongly polluting fossil resources, such as coal and oil, shale gas extraction could prove to have lower energetic requirements, then it may acquire a relative viability. On the end of the chain new technologies on the use of Natural gas are being developed, hence of shale gas as well (Celanese, 2011; Coskata, 2008; Johnston, Chen, Kimmich, Chapman, & Zink, 2011), and these conversion methods are enhancing its energetic viability.

Having recognized how sensitive viability criteria can be once you decide to examine more carefully and consciously the processes, it is possible to widen the conversion paths considered, to include solutions that may have been carelessly overlooked at first.

One of these options is the conversion of shale gas into ethanol. A proper comparison with the life cycle approach has thrown some new light on the convenience of the regular corn-based ethanol over other synthesis possibilities. That said, recently a few companies claimed to have the technology to convert fossil fuels into ethanol. For example, the first company with this claim is Celanese through the catalytic and thermochemical pathway process which is called TCX® Technology (Celanese & BUS, 2011). This technology is based on the acetyl platform as can be seen in **Figure 5**, and also includes some high-quality processes. The process uses hydrocarbons to produce ethanol, instead of any other feedstock. The main advantages of this technology are the high-quality, low-cost ethanol for liquid transportation fuel (Johnston et al.,

2011; Joo, Jung, Han, & Uhm, 1995). The company states that the production of ethanol can be achieved at a cost of US$60 per barrel of crude oil, around US$1.50 per gallon.

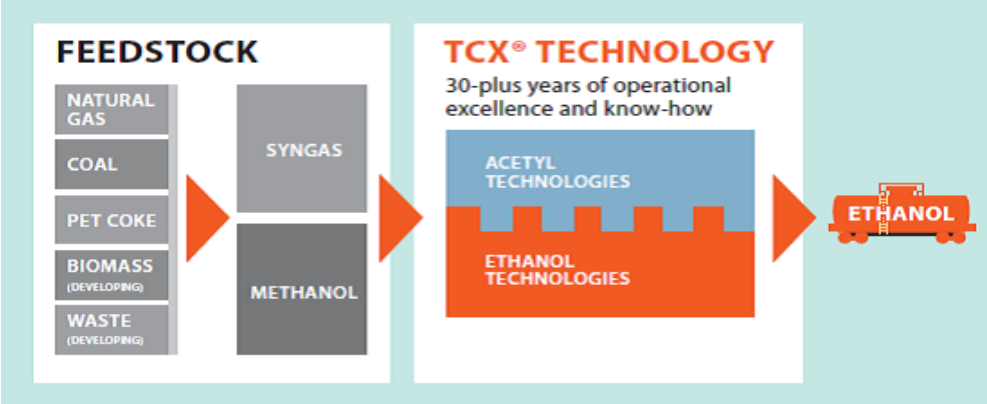

Figure 5: TCX® technology diagram (Celanese, 2011)

A second way of producing ethanol is through the biochemical pathway by Coskata's technology (Coskata, 2008) using carbon-containing feedstocks in order to produce a variety of alternative fuels. A summary of the process itself is shown in **Figure 6**. Their claim is simple; they say the U.S will have an increment of 15 billion gallons of ethanol if only 10% of the natural gas is used as for this process. Another interesting point is the efficiency of the process that can produce 7 gallons of ethanol per mmBTU of natural gas. In addition to all this, the syngas process is conducted at low temperatures and pressure, so the final costs are not increased.

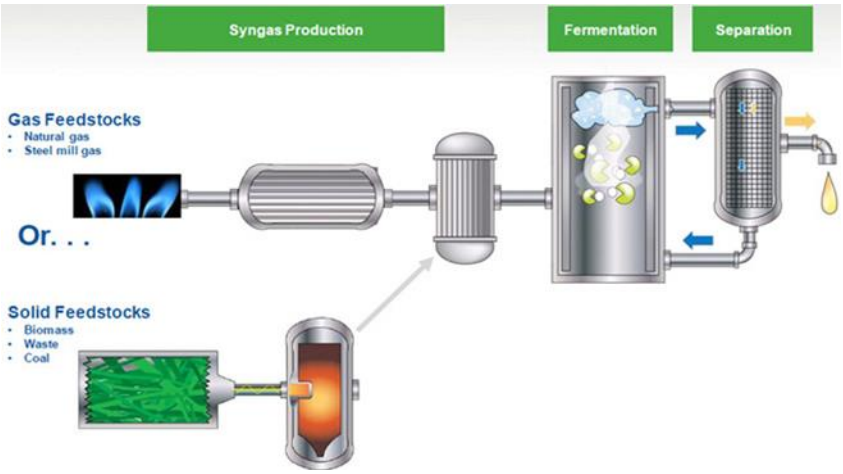

Figure 6: Coskata's process (Coskata, 2008)

Another company which proposed the biochemical pathway in **Figure 7** for this process is LanzaTech with its joint venture with Siemens for 10 years, starting in 2013. The technology (Lanzatech, 2008) uses a fermentation process to transform CO and CO2 from steel plants into ethanol. This technology will reduce significantly the gases that have been flared to the environment by this industry, and allow us to see another option for the production of ethanol different than corn crops.

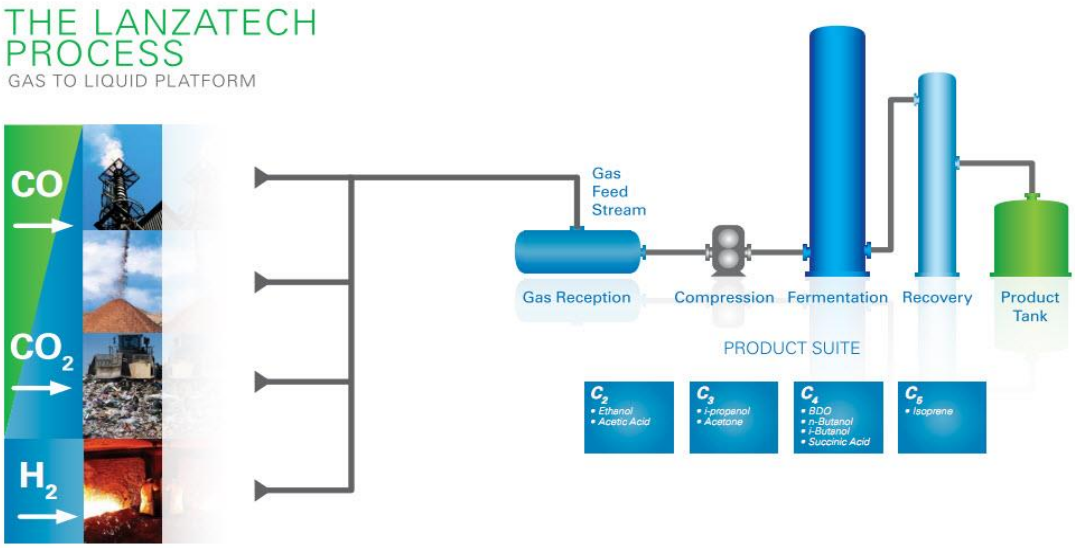

Figure 7: LanzaTech process (Lanzatech, 2008)

In this chapter, we made a LCA comparison for both processes. We analyze the complete process, and then each of the main components where studied. Now the reader can have a better understanding of the environmental aspects involved in this research.

Research objective

Evaluate and compare the technical, environmental, and economic aspects of ethanol production from corn and shale gas.

General approach

We propose to divide the LCA into four different elements – water use, atmosphere pollution, land use, and energy, in each of which there are significant opinions and studies already that are summarized in the following chapters.

In general, we compared the sustainability aspects of ethanol production from corn and shale gas focusing on domestic use that has to do with the Domestic Fuel Solution Group (DFSG) and the companies with the conversion technologies. The evaluation and comparison considered the following elements of a LCA:

1. Water
2. Atmosphere
3. Land
4. Energy

The best way to make a comparison of this level is through a Life Cycle Analysis. For this specific case the LCA was performed from crops to pump for corn, and well to pump in the case of shale gas.

Research overview

To be able to achieve our research objective, we had to perform the following tasks:

1. Literature review of:
    - Life Cycle Analysis
    - Ethanol production from Corn
    - Ethanol production from Shale Gas
2. Collection of data for inventory purposes
3. Implementation of a general LCA methodology
4. Technical, environmental, and economic comparison

Chapter I gives an outline of the general topic of this thesis. We begin with background information about the LCA, and on the process of making ethanol from corn, and ethanol from shale gas. We present the research objective, the general approach implemented the research overview and the thesis overview.

Chapter II involves the technical aspects of ethanol from corn, and from shale gas. The two processes were selected, and an Aspen Plus simulation was performed.

Chapter III contains the Life Cycle Analysis, which includes four main aspects of this comparison; water, atmosphere, land, and energy. This LCA provides a support for our environmental comparison.

Chapter IV is the general economic aspects of these two processes, this chapter is not intended to be a complete economic analysis, but to give an overview of direct and indirect costs.

Chapter V summarizes the four main aspects studied such as land, energy, atmosphere and water.

Chapter VI shows the main findings of the research, where we make our conclusions on the aspects encountered in this thesis.

CHAPTER II

ETHANOL PRODUCTION PROCESSES

Chapter II simulates processes for making ethanol. The first section addresses making ethanol from corn, and the second one addresses making ethanol from natural gas. After describing processes found in the literature, simulation inputs are listed for a selected process. The software used was Aspen Plus, an oil and gas simulation software. We build a block diagram first for ethanol from corn, and shale gas including mass and energy. Then we selected a process for the analysis, we built the process diagram on Aspen, finally we input the data to perform the simulation.

Ethanol from corn process description

The production process evaluated for this conversion is the "Dry milling process" because it requires less capital investment, fewer personnel to operate the plant, and is more flexible. In addition, about 88% of ethanol production from corn in the United States, is conducted through this process (Wood, 2014).

According to (Bothast & Schlicher, 2005), this process is designed to obtain the maximum amount of ethanol. The characteristics such as enzyme quantity, yeast quality, and operating conditions of the main stages, as well as the design itself, were based on (Mosier & Ileleji, 2012), (RFA, 2014), (Chaplin, 2014) and (Kwiatkowski, McAloon, Taylor, & Johnston, 2006). **Figure 8**, shows results for the simulation we developed in Aspen for the dry mill process.

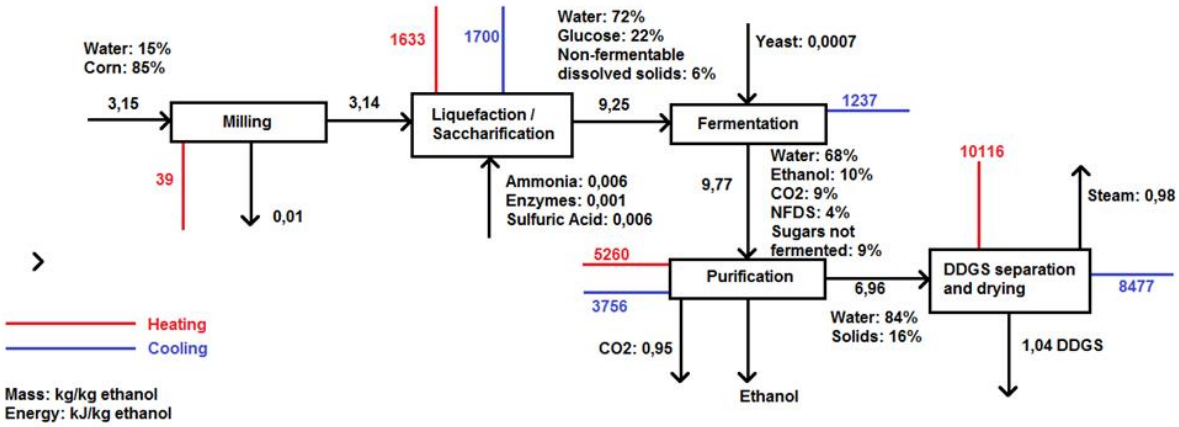

Figure 8: Mass and energy diagram for ethanol from corn

For the "dry milling process" the entire grain is treated, and the remaining components go through a separation process at the end. It is based on five main stages; milling, liquefaction and saccharification, fermentation, purification, Dried Distillers Grains with Soluble (DDGS) separation and drying, as can be seen on the previous diagram. This next section will explain the process and the results obtained from the simulation in terms of mass and energy.

Liquefaction and saccharification reaction: the following is the reaction used for the liquefaction and saccharification process for ethanol production:

$C_6H_{10}O_5 + H_2O \longrightarrow C_6H_{12}O_6$

Fermentation reaction: the fermentation reaction is the following:

$C_6H_{12}O_6 \longrightarrow 1.9\ C_2H_5OH + 1.9\ CO_2 + 0.06\ C_6H_{12}O_6$ (non-fermentable)

Required feedstock quantity (kg/kg ethanol):

a) **Milling:** this is the first stage of the process, and is where the corn grains are milled in order to produce a corn flour by using a hammer mill. The corn flour is then mixed with water and enzymes. The following is the feedstock entry to this process:
   - Corn: 2.68 (85% of 3.15) [See Figure 4]
   - Water: 0.47 (15% of 3.15) [See Figure 4]

b) **Liquefaction:** process is where the mixture is cooked using temperatures above 212°F. The heaters are called jet-cookers and inject steam to the corn flour. Within the process, the starch is separated and the enzymes help fragment it into small pieces. The second step is to let the slurry cool down, and add more enzymes to finally liquefy again for 30 minutes.
   - Ammonia: $6.25x10^{-3}$
   - Enzymes: $9.35x10^{-4}$

c) **Saccharification:** is the step where the slurry is cooled down and takes the name of corn mash. More enzymes are added in order to break down the glucose. This process occurs when the corn mash is placed in the fermenter and through the fermentation process as well.
   - Enzymes: 9.36011E-05
   - Acid: 0.006258909

d) **Fermentation:** is the longest process and takes over 48 hours to let the glucose converts into ethanol by adding yeast. The process occurs in batches and in this step the carbon dioxide is produced. After fermentation the mash is called beer, and placed for storage in beer wells.

- Yeast: 7.81×10^{-4}

e) **Purification:** is also called fractional distillation and mainly consist on separating all components by evaporation when heating them.

- Water: 0.66

f) **DDGS (Dried Distillers Grains with Soluble) separation and drying:** the remaining water is adsorbed by molecular screens, coming to almost 99% of ethanol. The solids are separated using centrifugation, and then evaporators to take out the water to produce the syrup. When this syrup is mixed with grains from purification and dried, becomes DDGS used as an animal food.

- There is no feedstock entry to this process

Effluents (kg/kg ethanol):

a) **Milling:**

- Corn: 8.04×10^{-3}
- Water: 1.41×10^{-3}

b) **Liquefaction:**

- There is no effluent to this process

c) Saccharification:

- There is no effluent to this process

d) Fermentation:

- There is no effluent to this process

e) Purification:

- Water: 3.83×10^{-3}
- Carbon Dioxide: 7.66×10^{-4}

f) DDGS separation and drying:

- Water: 0.98 (vapor)
- DDGS: 1.04

Required energy for industrial use (kJ/kg ethanol):

a) Milling:

- Heating: 39.5
- Cooling: 0

b) Liquefaction:

- Heating: 1633.23
- Cooling: 262.68

c) **Saccharification:**

- Heating: 0
- Cooling: 1437.95

d) **Fermentation:**

- Heating: 0
- Cooling: 1237.36

e) **Purification:**

- Heating: 5195.34
- Cooling: 2256.7

f) **DDGS separation and drying:**

- Heating: 10116.35
- Cooling: 8477.83

Total energy required for industrial use:

- Heating: 17049.69
- Cooling: 15172.57

Figure 9 is a summary of the information obtained through the simulation regarding the energy requirements for heating and cooling among the entire process:

Ethanol from Corn Process kJ/kg ethanol			
Energy	Heating	Cooling	Total
Milling	39.49514291	0	39.4951429
Liquefaction	1633.229072	262.6790893	1370.54998
Saccharification	0	1437.950547	-1437.9505
Fermentation	0	1237.355163	-1237.3552
Distillation	5195.336936	2256.703593	2938.63334
Dehydration	65.27430874	1500.048204	-1434.7739
Separation and drying de DDGS	10116.35046	8477.830194	1638.52026
Total	17049.68592	15172.56679	1877.11913

Figure 9: Ethanol from corn simulation process

Figure 10 represents the inputs and outputs for the simulation process:

	Milling	Liquefaction	Saccharification	Fermentation	Distillation	Dehydration	Separation and drying de DDGS
Inflowing							
Corn	2.68178813	0	0	0	0	0	0
Water	0.47325673	0	0	0	0.66753671	0	0
Ammonia	0	0.006258909	0	0	0	0	0
Enzymes	0	0.00093581	9.36011E-05	0	0	0	0
Acid	0	0	0.006258909	0	0	0	0
Yeast	0	0	0	0.000781628	0	0	0
Effluent							
Water	0.00141977	0	0	0	0	0.003832386	0.981802208
Corn	0.00804536	0	0	0	0	0	0
CO2	0	0	0	0	0	0.000766451	0
DDGS	0	0	0	0	0	0	1.041263847
CO2	0	0	0	0	0	0	0.955014048

Figure 10: Inputs and outputs from ethanol from corn in kg/kg ethanol

The Corn simulation workflow can be found in **APPENDIX A**.

The Corn simulation currents can be found in **APPENDIX B**.

Ethanol from natural gas process description

During the past years, the gas reforming technology has been under development, and today there are different research topics on this subject. The commercial processes diagrammed in

Chapter 1 do not provide sufficient detail for the LCA analysis. The reactions, conditions, and process diagrams for our analysis were taken from (Farniaei, Abbasi, Rahnama, Rahimpour, & Shariati, 2014); (Jechura, 2015), (Simpson & Lutz, 2007) and (Gangadharan, Kanchi, & Lou, 2012). The reactions for the fermentation process of syngas were based on (Younesi, Najafpour, & & Mohamed, 2006); (Liu et al., 2014), (Rao, 2005), (Kasteren, Dizdarevic, Van der Waall, Guo, & Verberne, 2005) and (Gangadharan et al., 2012). In **Figure 11** can be observed the block diagram for the ethanol from shale gas conversion process.

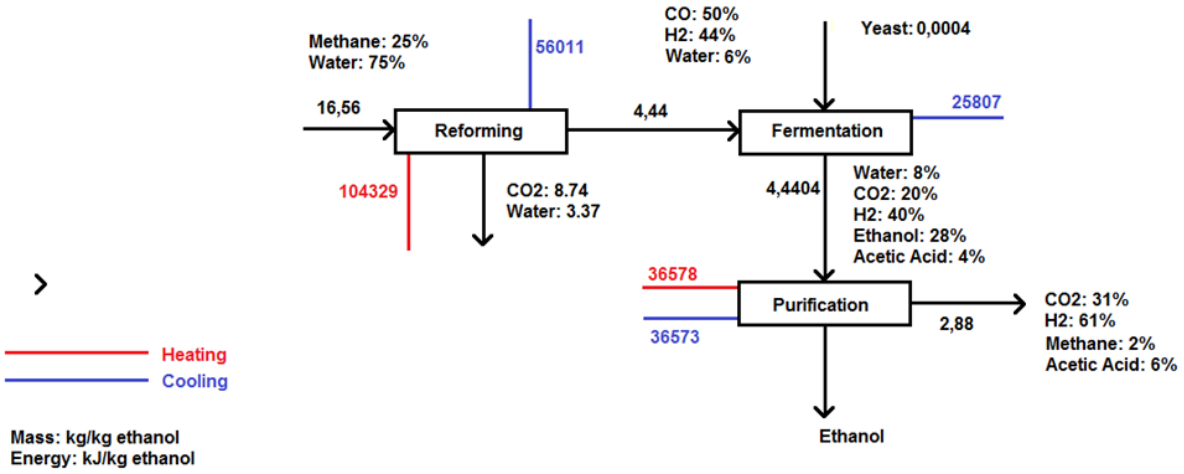

Figure 11: Mass and energy diagram ethanol from shale gas

In the previous figure, the main three stages of this process are shown. The following is the process and calculations for shale gas conversion to ethanol and an explanation of each of the phases:

Reforming reactions (equilibrium):

The following are the equations used in the reforming reaction:

$CH_4 + H_2O <--> CO + 3H_2$

$CO + H_2O <--> CO_2 + H_2$

$CH_4 + CO_2 <--> 2CO + 2H_2$

Fermentation reaction: for fermentation reaction, the equations are:

$2CO_2 + 6H_2 \rightarrow CH_3CH_2OH + 3\ H_2O$

$6CO + 3H_2O \rightarrow C_2H_5OH + 4CO_2$

$3CO + 3H_2 \rightarrow C_2H_5OH + CO_2$

$2CO + 4H_2 \rightarrow C_2H_5OH + H_2O$

$4CO + 2H_2O \rightarrow CH_3COOH + 2CO_2$

Required feedstock quantity (kg/kg ethanol):

a) **Reforming:** this is the first step of the process, where the natural gas is transformed to a synthesis gas by changing its molecular structure using high temperatures. As the name in tales, this is how the main component in gas which is methane; is reformed in order to become a syngas.
    - Methane: 4.22 (25% of 16.56)
    - Water: 12.33 (75% of 16.56)

b) **Fermentation:** is the second stage of the process where the bacteria are in charge of the transformation of syngas into a fermented mixture to be converted in the next step into the desired product.
    - Yeast: $3.55x10^{-4}$

c) **Purification:** this third and final step of the gas conversion to ethanol, here is mainly where the components are separated by evaporation to come out with a fuel grade ethanol.

- There is no feedstock entry to this process

Effluents (kg/kg ethanol):

a) **Reforming:**

- Carbon Dioxide: 8.74
- Water: 3.37

b) **Fermentation:**

- There is no matter as effluent

c) **Purification:**

- Carbon Dioxide: 0.88
- Water: 0.010
- Methane: 0.043
- Acetic Acid: 0.14
- Carbon Monoxide: 0.022
- Hydrogen: 1.75
- Ethanol (during CO2 absorption): 0.037

Required energy for industrial use (kJ/kg ethanol):

a) **Reforming:**

- Heating: 104329.33
- Cooling: 56011.38

b) **Fermentation:**

- Heating: 0
- Cooling: 25807.14

c) **Purification:**

- Heating: 36578.05
- Cooling: 36573.88

From **Figure 12** can be seen a summary of the energy required for heating and cooling in every stage of the process.

Ethanol from Shale Gas Process kJ/kg ethanol			
Energy	Heating	Cooling	Total
Reforming	104329.3378	56011.38289	48317.95491
Fermentation	0	25807.14202	-25807.142
Purification	36578.05421	36573.88825	4.165961418
Total	140907.392	118392.4132	22514.97885

Figure 12: Ethanol from shale gas process

The following **Figure 13**, represents the input and output currents from the process:

	Reforming	Fermentation	Purification
Inflowing			
METHANE	4.226122099	0	0
WATER	12.33892479	0	0
YEAST	0	0.000355338	
Effluent			
CO2	8.745632915	0	0.88053753
WATER	3.37760688	0	0.01095419
METHANE	0	0	0.04300973
ACETIC ACID	0	0	0.14256897
CO	0	0	0.02216622
H2	0	0	1.75339649
ETHANOL	0	0	0.03706031

Figure 13: Inputs and outputs from ethanol from corn in kg/kg ethanol

The Shale gas simulation workflow can be found in **APPENDIX C**.

The shale gas simulation currents can be found in **APPENDIX D**.

In this chapter, we made a simulation for the two processes of study; ethanol from corn, and ethanol from shale gas. We used calculations taken from the literature, and the help of Aspen Plus in order to simulate the two currents with real data.

CHAPTER III

LCA OF ETHANOL PRODUCTION PROCESSES

Chapter III described processes for making ethanol from corn and from natural gas. In this chapter, we examine the processes from a Life Cycle Analysis (LCA) perspective. After a brief description of this approach, the analysis is done considering LCA implications on water, atmosphere, land, and energy for each of the processes detailed in Chapter II.

Life cycle analysis methodology

Our specific methodology is illustrated in **Figure 14**:

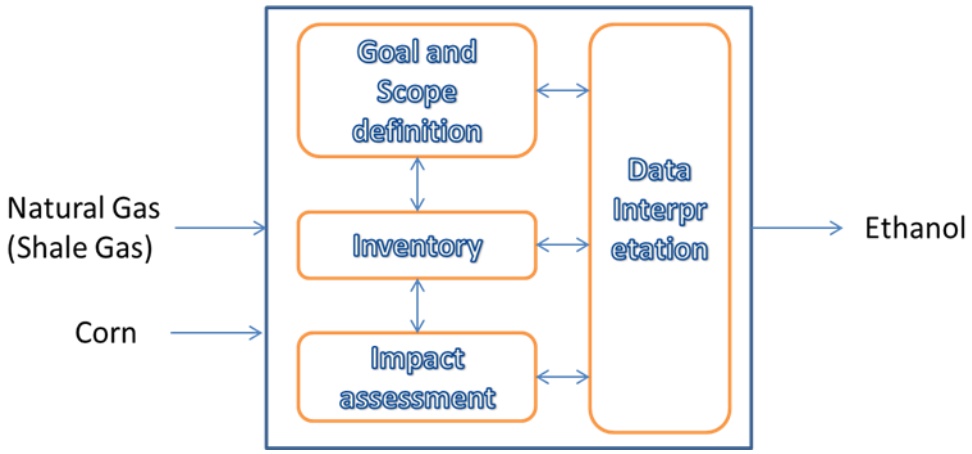

Figure 14: Life cycle analysis: well to wheel and crop to wheel

LCA implications for water

This section explains the LCA implications on water first for making ethanol from corn and then for making ethanol from natural gas.

(Mishra & Yeh, 2011) stated the water issues for corn ethanol concern their need both for large volumes of water for the irrigation process and for the conversion process to ethanol. We should take into account as well, the variety of byproducts obtained as we convert the raw matter into the specific desired product.

Some aspects that have been taken into account by (Mishra & Yeh, 2011), so far in the evaluation of the water life cycle of corn-based ethanol are: water requirements for corn harvesting; water intensity of ethanol; impact on water demand; and what was originally predicted versus the real data. These issues respond to the distribution of water sources such as precipitation, surface or groundwater. (Mishra & Yeh, 2011) show in **Figure *15***, that some states in the U.S have a high dependence on precipitation, which is a highly variable resource and will have a direct impact on harvesting efficiency.

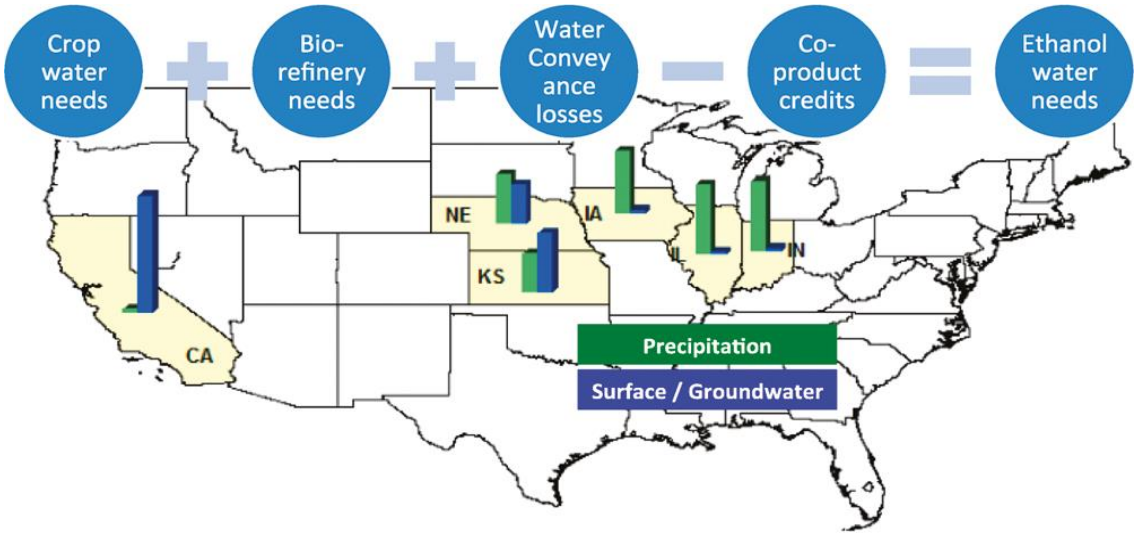

Figure 15: Water life cycle (Mishra & Yeh, 2011)

Ethanol from natural gas water aspects

The Environmental Protection Agency (EPA) has been studying the potential impacts of hydraulic fracturing on drinking water resources for multiple years due to the claims presented to the government accusing water contamination due to hydraulic fracturing in different states, such as Texas, North Dakota, Pennsylvania, Colorado and Louisiana. EPA released in 2012 a progress report on how hydraulic fracturing impact drinking water, they state that there are potential mechanisms by which this stimulation technique could contaminate drinking water either above or below the ground, however, no evidence was found that these mechanisms have led water contamination; There was a small number of cases reported with water contamination due to hydraulic fracturing, however, they are small relative to the number of wells drilled. This could reflect the low probability of water contamination; however more data is needed in order to corroborate this statement. (U. S. E. P. A. EPA, 2012) **Figure 16** shows the water cycle during a typical hydraulic fracturing treatment.

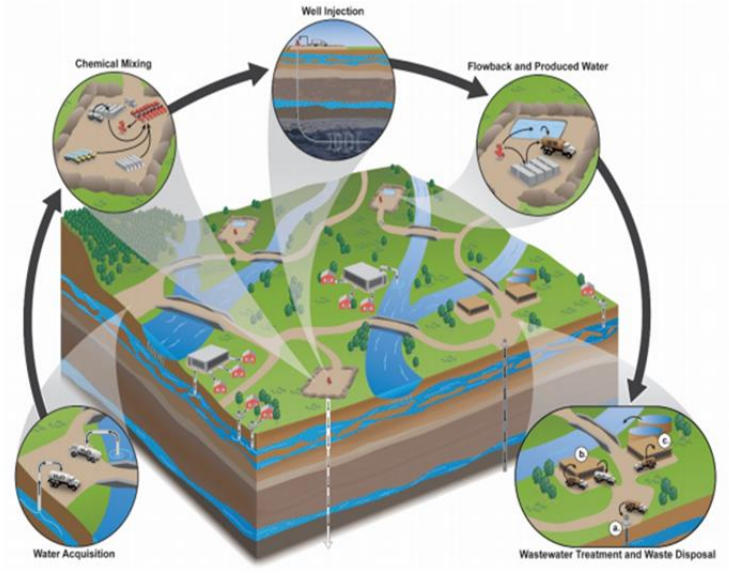

Figure 16: Water cycle for hydraulic fracturing (U. S. E. P. A. EPA, 2012)

There have been several reports that state the lack of evidence of water contamination due to hydraulic fracturing, MIT Energy Initiative states that shallow waters can be contaminated with the hydraulic fracturing fluids, but there is no actual proof this is happening (Massachusetts Institute of Technology., 2010). The U.S. geological Survey after studying multiple samples of shallow groundwater from the Fayetteville Shale gas production area, found that there are not effects on shallow groundwater contamination in this area (Kresse et al., 2012). The literature has identified multiple water resources contamination risks associated with shale gas development and hydraulic fracturing. However, the evidence of water contamination is not clear due to the lack of data related to the baseline water chemistry of aquifers before and after shale gas exploration, therefore the water contamination statements remain uncertain (Vengosh, Jackson, Warner, Darrah, & Kondash, 2014).

Using Aspen simulation process for water calculations we obtained the water inputs and outputs for both scenarios. In **Figure 17** one can see the total water consumption during the corn to ethanol method and shale gas to ethanol.

Ethanol Production Water Requirements [kg/kg ethanol]		
	Corn Process	Shale Gas Process
Required Feedstock	1.140793435	12.33892479
Effluent	0.987054365	3.37760688
Total	0.15373907	8.961317914

Figure 17: Water requirements aspen

In this comparison, we observe a difference of over 58 times, one could think this will make the shale gas process unviable, but we are missing the previous stage were most controversy

emerge. The water used during hydraulic fracturing against the water used for harvesting the corn. The calculations used as a reference for this comparison are from (Muhlenkamp, 2012); coming to a 14,000 for hydraulic fracturing, to 1 ratio for water efficiency from harvesting corn these calculations were based on the production of gasoline, but we made the same assumptions but for 1 gallon of ethanol to add this number to our ethanol production process. A summary of his calculations are as follow:

Corn process:

Rain for crops: 25 inches, 2.08ft

Corn yield: 147 bushel /acre

1 bushel yield: 2.77 gal ethanol

1 acre: 43,560sqft

Ethanol production = 147 bu/acre x 2.77 gal/bu = 407.19 gal ethanol

Water required for corn = 2.08ft x 43,560sqft x 7.48gal/sqft = 677,724 gal water

The ethanol production is 407.19 gallons of ethanol per acre, and it requires for this production 677,724 gallons of water.

Water required = 677,724 gal water / 407.19 gal ethanol = 1,664.39 gal water / gal ethanol.

Shale gas process:

Water used for drilling: 65,000 – 650,000

Water for hydraulic fracturing: 4.5M gal

Marcellus typical drains: 80 acres

Lifetime production: 4 BCF

Energy in natural gas: 900 BTUs/cft (lower heating value)

Energy in ethanol: 76,330 BTU/gal (lower heating value)

Production/acre = 4 BCF / 80 acres = 50 MMCF/acre

Energy/acre lifetime gas= 50 MMCF/acre x 900 BTU/cft = 45 billion BTU/acre

Energy/acre ethanol = 45 billion BTU/acre / 76,330 BTU/gal = 589,545 gal/acre

The approximate water for drilling and hydraulic fracturing is 5 million gallons,

Water input = 5 Mgal / 80 acres = 62,500 gal/acre

Water required = 62,500 gal/acre / 589,545 gal/acre = 0.11 gal water/gal ethanol

This well will require 0.11 gallons of water in order to produce the energy of 1 gallon of ethanol from shale gas.

Now we want to add this value to the one obtained from the Aspen simulation. We need them to be in the same units so we convert 0.11 gallons of water per gallon of ethanol to kg of water per kilogram of ethanol by using the ethanol density of 789kg/m3 and the water density of 1000kg/m3, which gives us a value of 0.14kg water/kg ethanol. We did the same for corn ethanol and from 1,664.39 gal w/gal ethanol we obtained 2,109.5 kg w/kg ethanol.

The total water for drilling, hydraulic fracture, and ethanol production from shale gas is:

Total Water shale gas = 0.14 kg w/kg ethanol + 8.96 kg/kg ethanol = 9.1 kg w/kg ethanol

The total water for corn crops and production process of ethanol is:

Total Water corn = 2,109.5 kg w/kg ethanol + 0.15 kg w/kg ethanol = 2,110 kg w/kg ethanol

We have a difference in water efficiency of 234 times from shale gas versus ethanol.

2,110 kg/kg ethanol / 9,1 kg/kg ethanol = 234

A summary of this results can be seen in **Figure 18**:

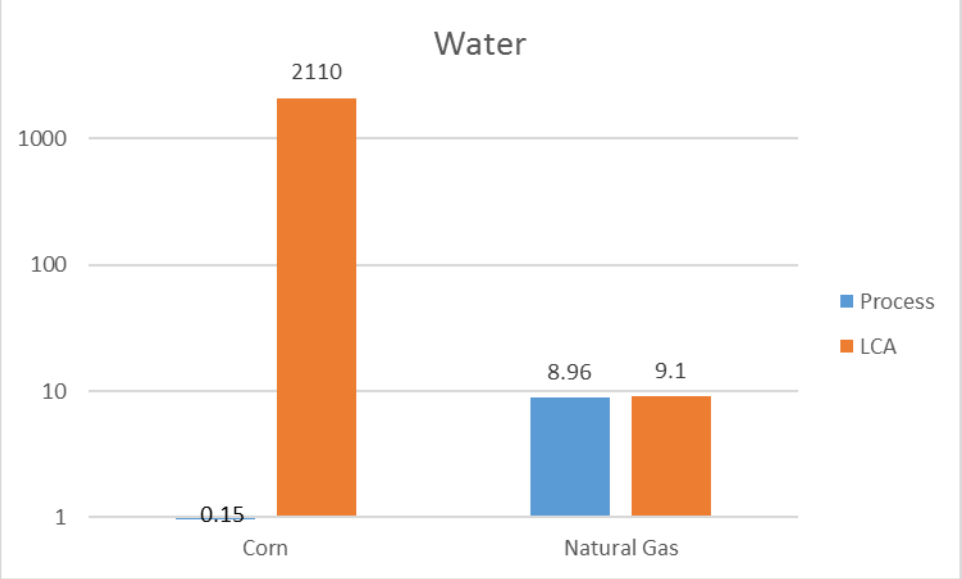

Figure 18: Water implications for the conversion process (blue) and the entire LCA (orange)

LCA implications for atmosphere

This section explains the LCA implications on atmosphere for making ethanol from corn and then for making ethanol from natural gas.

Ethanol from corn atmospheric aspects

(Wiedmann & Minx, 2008) claimed that impact of any activity, industrial or not, is now frequently measured in terms of carbon dioxide and other GHG gases necessarily emitted by its performance. That means having most environmental comparisons developed in terms of Carbon Footprint, for example. According to (Seinfeld & Pandis, 2006), there are different kinds of atmosphere pollution, and also direct and indirect causes for a series of atmospheric

anomalies, but Green House Gases (GHG) are definitely a major issue in life cycle methodology. In response of this, when the atmosphere pollution is addressed particular attention to the GHG phenomena is intended, as well as a more direct cause-consequence relation. Again, the scope should be specified clearly in this topic as in the rest, because indirect causes, as quantified by (Matthews, Hendrickson, & Weber, 2008) represents 86% of the supply chain carbon emission, in average.

Corn-based biofuels have compared performance data, particularly for corn-based ethanol. Improvements in the total GHG emissions were reported by (Hill et al., 2006) at 12%, by the combustion and synthesis of corn-based ethanol relative to fossil fuels. On the same line of discussion, but on the opposite end, (Yi, Junghan, Junbeum, & Sangwon, 2012) claim to have a better inclusion of agricultural practice differences report greater environmental impacts for high percentage mixtures of gasoline ethanol, between 23 and 33% depending on direct or indirect considerations. Evidently there are differences in the targets and broadness of these researches, yet the results tend to reviews in past laws and prudence in future ones.

Ethanol from natural gas atmospheric aspects

Shale gas as a fossil fuel may pose an apparent prejudice to environmental conservation. According to certain considerations, such as the amount of each GHG type and the global warming potential (GWP) of them, the environmental effect can get desirable as stated by (EPA, 2010; Shindell et al., 2009) or undesirable according to (Howarth, Santoro, & Ingraffea, 2011) in relation to other energetic sources. Different stages of the shale gas extraction represent different GHG emissions. An example of this situation can be seen in the GHG

emissions from the Marcellus field in Figure 19. The mentioned variety of conditions in the shale gas extraction is manifested when objections regarding time period analysis as studied by (Lashof, 2011) or fugitive emissions studied by (Cathles, Brown, Taam, & hunter, 2012), become tools on one side or the other. Although it tends to incline towards the convenience of the shale gas for both, the governmental analysis by (Skone, 2011) and academic side (Hultman, Rebois, Scholten, & Ramig, 2011; Jiang et al., 2011), make the discussion itself continue and opens the door for further comparisons.

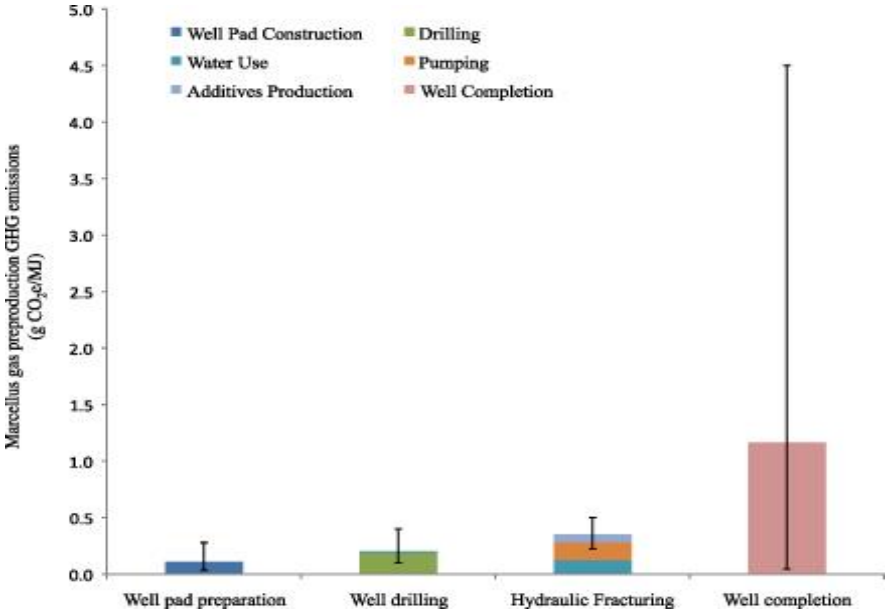

Figure 19: GHG emissions example: Marcellus field (Mohan et al., 2011)

For this calculations we need to recall the results obtained from the energy calculations from our Aspen simulation. With energy use as a proxy for CO_2 emission, we obtain the reciprocal value from the efficiency.

Produced energy / required energy ratio (heating) corn: 26,800*/17,049.69 = 1.5719

*Lowest calorific power of ethanol in kJ/kg ethanol (Kim & Dale, 2005)

$Emissions_{corn}$ = 17,049.69/26,800 = 0.64

Produced energy / required energy ratio (heating) shale gas: 26,800*/140,907.32 = 0.1902

*Lowest calorific power of ethanol in kJ/kg ethanol (Kim & Dale, 2005)

$Emissions_{shalegas}$ = 140,907.32/26,800 = 5.26

Emission comparison = $Emissions_{shalegas}$ / $Emissions_{corn}$ = 5.26 / 0.64 = 8.21

Now we know that shale gas produces 8.21 more emissions than corn ethanol, so we need to add this values to calculate the total emissions from both corn and shale gas ethanol for the

LCA Assumptions:

Corn emissions: 1 gCO2e/MJ

Shale gas emissions: 8.21 gCO2e/MJ

From (Wang et al., 2011) we get the 75 gCO2e/MJ for the total of values for combustion, harvesting, the uptake of CO2 from biomass growth, chemical in field, and chemicals in manufacturing. From (Yaritani & Matsushima, 2014) we obtained the 14.6 gCO2e/MJ for the preproduction, production, and transmission emissions from shale gas.

Corn total emissions = 75 gCO2e/MJ + 1 gCO2e/MJ = 76 gCO2e/MJ

Shale gas total emissions = 14.6 gCO2e/MJ + 75 gCO2e/MJ + 8.21 gCO2e/MJ = 97.81 gCO2e/MJ

Total emission ratio = Shale gas total emissions / Corn total emissions

Total emissions ratio = 97.81 gCO2e/MJ / 76 gCO2e/MJ = 1.29

With the LCA we can observe a difference between the two processes emissions of 1.29, when we include all the considerations for the preproduction, production, transmission and combustion of fuels for harvesting and producing shale gas.

LCA implications for land

This section explains the LCA implications on land for making ethanol from corn and then for making ethanol from natural gas.

Ethanol from corn land aspects

This is a manifold aspect to evaluate due to the different ways in which land can affect environmental issues altogether. For instance, abnormal concentrations of agrochemicals in a given space is a valid indicator of a land type environmental impact. Depletion of the soil nutrients, ecosystem eradication or food scarcity are also valid impacts. Now, the phenomena mentioned are of a more direct kind. Lately, a universal expression of the environmental impact of any activity is the amount of carbon dioxide required to perform it. This said, the literature on this matter frequently use the carbon footprint indication to present results and conclusions regarding the changes or alterations suffered by the landscape.

As for the corn cultivation, the primary focus lies in the implications of the purpose. This means, in general for other biofuel industries as well, that harvesting for meeting the energetic demand, even partially, would require intensification or extensification of the available land usage. The corn ethanol yield compared with other crops makes this consideration critical, given it is almost half of sugar cane ethanol yield per acre.

The intensification does not offer sufficiently fast answers, and those it can provide could potentially exacerbate the effect of fertilizers, pesticides and other agricultural inputs (Yi et al., 2012). Regarding the extensification option, two types of impact must be observed: The direct and the indirect. Extend the land available for harvesting the grain in order to keep the food stock intact, would imply not only larger impact on the soil itself but the generation of an extra carbon footprint, CO2 and other GHG emission, originated by the release of the carbon captive in the preceding vegetation occupying the land (Fargione et al., 2008). This process accounts for the direct impact, for the indirect one, it is necessary to introduce the satisfaction of the food demand by other countries if a part of the U.S. offer is deviated to energetic use. This external change in land use also implies an environmental impact (Searchinger et al., 2008).

Ethanol from natural gas land aspects

In terms of space occupied and permanently altered, shale gas requires it for equipment, water and chemicals storage and transportation. Generally, many wells are drilled near one and other, using between 16 and 20 thousand square meters at first, and between 4 and 12 thousand once partially restored. Following, the well density depends not only on the field characteristics but on the state regulations. This density, for the U.S., as stated by (ENVI, 2011), averages 1 well each 2.6 square kilometers. As said before, well specifications can vary widely depending on its exploitation conditions, so there are fields with 1.5 or up to 6 wells per square kilometer. Nonetheless, when the implementation of ponds for the storage of backflow water is included, the well pad mentioned could easily duplicate.

Recalling our calculations made for water; the ethanol production from corn is 407.19 gallons of ethanol per acre, and for shale gas is 589,545 gal/acre. If we want to produce the same gallons we obtained from shale gas, we will need:

Land estimation = 589,545 gal/acre / 407.19 gal/acre = 1,447.83 acres

This is 1,447.83 acres of land to produce the same gallons from 1 acre of shale gas production. **Figure 20** represents the land comparison for ethanol from corn, and ethanol from shale gas.

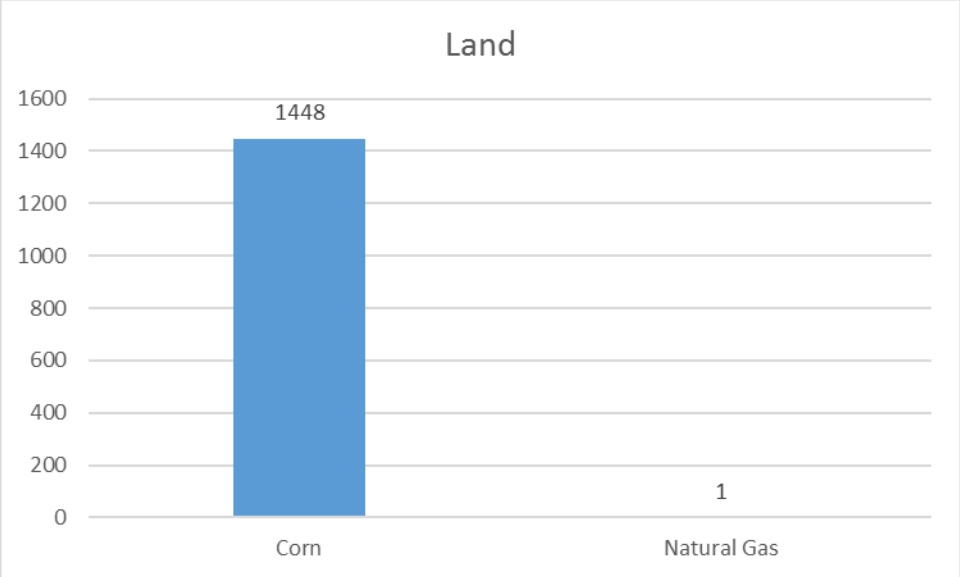

Figure 20: Land implications

Another aspect we should consider, is the fact that the drainage area per acre for shale gas is through multiple wells using only one pad. horizontal wells which account for a surface footprint of about 1%.

LCA implications for energy

This section explains the LCA implications on energy for making ethanol from corn and then for making ethanol from natural gas. We recall the calculations made through Aspen to calculate the total energy for ethanol from corn and ethanol from shale gas processes:

Total energy required for corn to ethanol process:

- Heating: 17049.69
- Cooling: 15172.57

Produced energy / required energy ratio (Heating): 26800*/17049.69 = 1.5719

*Lowest calorific power of Ethanol in kJ/kg ethanol (Kim & Dale, 2005)

The corn simulation workflow can be found in **APPENDIX A**.

The corn simulation currents can be found in **APPENDIX B**.

Total energy required for shale gas to ethanol process:

- Heating: 140907.32
- Cooling: 118392.41

Produced energy / required energy ratio (heating): 26800*/140907.32 = 0.1902

*Lowest calorific power of ethanol in kJ/kg ethanol (Kim & Dale, 2005)

The shale gas simulation workflow can be found in **APPENDIX C**.

The shale gas simulation currents can be found in **APPENDIX D**.

In order to compare both efficiencies, we have to consider the entire process. For corn ethanol we used an estimate from the Department of Energy; which states that the production of 1mmBTUs of ethanol from corn, requires 0.78mmBTUs of fossil energy input (M. Wang, 2007) this will give an efficiency of:

E_{corn} = 1mmBTUs / 0.78mmBTUs = 1.2821

Comparing this value to what we obtained in the Aspen simulation: 1.5719 we can observe a similar value. We will be using the new efficiency since it is a more accurate value for the entire process and comprises the harvesting, transportation, and production of ethanol.

The shale gas has an efficiency of 13 to 23 energy return on investment (Yaritani & Matsushima, 2014) with a mean value of 17 for the extraction of shale gas. We need to use this value to calculate the efficiency of the shale gas conversion to ethanol, using the values from the Aspen simulation: 0.1902

$E_{shale\ gas}$ = 17 * 0.1902 = 3.2334

As can be seen in **Figure 21**, the energy required to produce ethanol from corn is over 2.5 times more, than the energy used in the production of ethanol from shale gas.

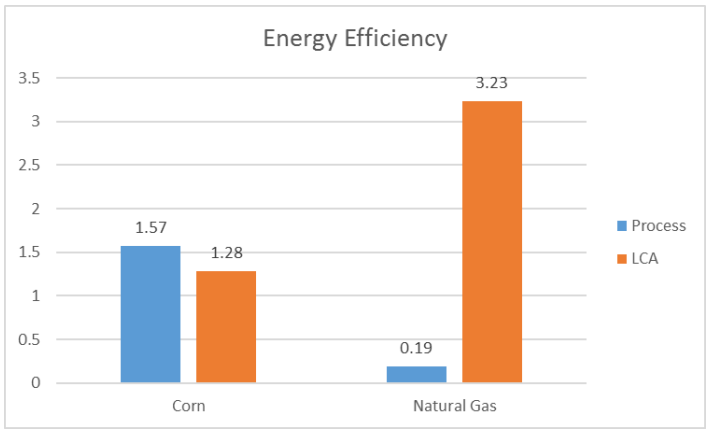

Figure 21: Energy efficiency comparison for the conversion process (blue) and the entire LCA (orange)

CHAPTER IV

ECONOMIC COMPARISON

In this chapter, the reader can find an economic comparison of these two processes. The costs named as direct, come from the specific technical processes used in this research. The indirect costs were taken from the LCA. Chapter IV is not intended to be a complete economic analysis, but to provide the reader with some keys to understanding the difference between the ethanol production paths in terms of cost. The future work will bring a detailed economic comparison of both scenarios.

Ethanol from corn has been a topic under study for the past years. Information is found to be more accurate than the one for natural gas estimations, **Figure 22** represents a plant cost for corn ethanol in the U.S for different capacities.

	Dry-mill	Wet-Mill
Corn	($0.868)	($0.902)
Co-Products	$0.340	$0.482
Net Corn Cost	($0.528)	($0.420)
Production Cost	($0.392)	($0.459)
Depreciation	($0.072)	($0.153)
Loan Payment	($0.053)	($0.114)
Total Cost	($1.045)	($1.146)
Ethanol Value	$1.250	$1.250
Return/Gallon	$0.205	$0.104
Return	$8,200,000	$4,160,000
Investment	18,000,000	38,560,000
ROI	45.6%	10.8%

Figure 22: Ethanol from corn plant cost 40 million gallon (Whims, 2002)

There are two main commercial companies with claims over natural gas to ethanol process and estimated costs. According to the Natural gas based liquid fuels study (Light, 2014) the first corporation is Coskata which reports the lowest price for the conversion of natural gas into ethanol by the use of an enzyme, with a $1.25 per gallon of product ethanol with feedstock gas price $4 per mmBtu. The second claim is by Celanese corporation with their TCX technology at about $2.35 per gallon of ethanol from coal. The following figure, **Figure 23** is a summary on the data provided by the study for this two main companies.

Company	Capital Investment million	Capital Investment per metric ton	Revenue per metric ton	Operating Cost per metric ton	Margin per metric ton	ROI
Coskata	$650	$1,128	$830	$313	$517	46%
Celanese TCX®	$2,500	$2,273	$830	$498	$332	15%

Figure 23: Ethanol from natural gas costs (Light, 2014)

Note: Coskata was out of business in 2015, but since this technology was taken into consideration at the beginning of this research, and the technology was transferred to Synata Bio; we are including this as a comment for the reader to know the real situation, but not to indicate that the technology is unavailable.

This comparison shows us how ethanol from corn and ethanol from shale gas can have a similar return on investment, we have to consider that ethanol from corn has been the only process accepted by mandate to blend with gasoline. The best process and technology for corn ethanol was selected, since the ROI for other plant sizes showed lower values, then the highest value

for natural gas conversion to ethanol was selected, showing a slightly higher value. We should also contemplate the learning curve of a new technology in order to be in equal basis. Corn from ethanol has been improving and lowering costs for the last years, and natural gas is a new technology trying to be considered. These topics will lead us to political aspects that are not considered in this thesis.

This chapter represents a basic comparison on the costs of the two processes studied. Each technology has its own claims, and there are different scenarios that must be considered in order to perform a complete economic analysis.

CHAPTER V

SUMMARY

This chapter contains a brief overview of the main findings and information gathered from different sources in order to make a comparison of the four main aspects considered in this study.

1. Water: from Aspen simulation and calculations

   The total water for drilling, hydraulic fracture, and ethanol production from shale gas is:

   Total Water shale gas = 0.14 kg/kg ethanol + 8.96 kg/kg ethanol = 9,1 kg/kg ethanol

   The total water for corn crops and production process of ethanol is:

   Total Water corn = 0.15 kg/kg ethanol + 2,109.5 kg/kg ethanol = 2,110 kg/kg ethanol

   We have a difference in water efficiency of 234 times from shale gas versus ethanol.

   2,110 kg/kg ethanol / 9,1 kg/kg ethanol = 234

2. Atmosphere: from Aspen simulation and calculations

   Corn total emissions = 75 gCO2e/MJ + 1 gCO2e/MJ = 76 gCO2e/MJ

   Shale gas total emissions = 14.6 gCO2e/MJ + 75 gCO2e/MJ + 8.21 gCO2e/MJ

   Shale gas total emissions = 97.81 gCO2e/MJ

   Total emission ratio = Shale gas total emissions / Corn total emissions

   Total emission ratio = 97.81 gCO2e/MJ / 76 gCO2e/MJ = 1.29

3. Land: from calculations

   Recalling our calculations made for water; the ethanol production from corn is 407.19 gallons of ethanol per acre, and for shale gas is 589,545 gal/acre. If we want to produce the same gallons we obtained from shale gas, we will need:

   Land estimation = 589,545 gal/acre / 407.19 gal/acre = 1,447.83 acres

   This is 1,447.83 acres of land to produce the same gallons from 1 acre of shale gas production.

4. Energy: from Aspen simulation and calculations

   The Aspen simulation lead us to a comparison between the two energy efficiencies obtained from both processes, as can be seen in the figure below:

CHAPTER VI

CONCLUSIONS

The following are some conclusions made from the study of the two processes and the findings obtained from the simulations.

1. The energy efficiency for making ethanol from corn, versus ethanol from shale gas, based on the Aspen Plus simulation lead us to state that from shale gas energy efficiency is more than 2.5 times that for corn.

2. With current advances on technologies, and claims made from different companies which stated to have a more efficient process such as: Celanese, Coskata, and LanzaTech; we believe there are different paths that can be used for the shale gas conversion to ethanol, leading to a better energy efficiency against corn ethanol.

3. Shale gas generated more emissions during the conversion process than ethanol from corn, this was considered under our predictions. Although, in the overall considerations for the LCA the difference between this two processes represents only a 1.3 difference better to ethanol from corn that to shale gas.

4. The process calculations, show a higher water usage for the conversion of shale gas into ethanol, but when we account for the main stages of drilling and fracturing the

well; the total water is actually over 200 times less water required to produce ethanol from shale gas than the required for harvesting and production of ethanol from corn.

5. Corn ethanol footprint is more than 14,000 times that for shale gas. Even improvements on efficiency from corn has been developed over the past years, there is no increment in technology that can get the value closer to the energy obtained from shale gas in terms of recovery.

6. Limited data was found for the ethanol from shale gas process, with advance on technology, improvements to the process and to the LCA, more accurate calculations can be performed as future work.

7. Similar ROI for ethanol from corn and ethanol from shale gas. The economic comparison allows us to see the proximity in ROI for ethanol from corn and ethanol from shale gas, meaning this is a viable option and there is room for improvement on this new technology, which can lead to better return on investment margins for natural gas to ethanol process.

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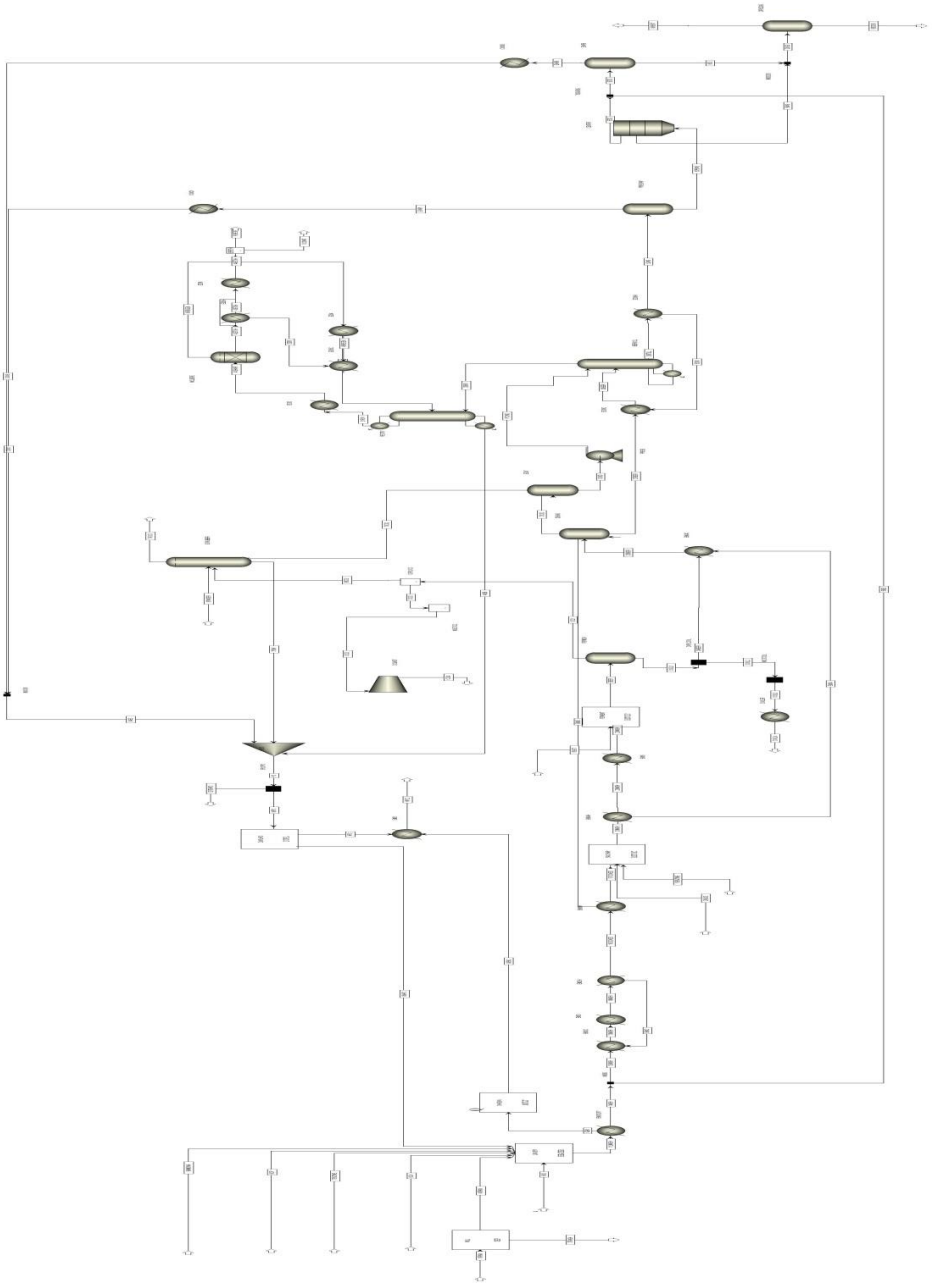
APPENDIX A

CORN SIMULATION WORKFLOW



APPENDIX B

CORN SIMULATION CURRENTS

		11LMASH	12MASH	13MASH	14MASH	16COOKED	17COOKED
From		**LIQUEFY**	**MIXBS**	**EM02C**	**EM03**	**EM02H**	**EM06H**
To		**EM01DUTY**	**EM02C**	**EM03**	**EM02H**	**EM06H**	**SACCHAR**
Substream: ALL							
Mass Flow	KG/HR	445935.1	524718.9	524718.9	524718.9	524718.9	524718.9
Mass Enthalpy	CAL/SEC	-372910200	-445745700	-444162400	-442679800	-444263000	-448952500
MASSFLOW							
WATER	KG/HR	299845.9	370692.2	370692.2	370692.2	370692.2	370692.2
ETOH	KG/HR	1347.09	1375.04	1375.04	1375.04	1375.04	1375.04
CO2	KG/HR	49	49	49	49	49	49
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	100612.9	100634.6	100634.6	100634.6	100634.6	100634.6
C5POLY	KG/HR	7474.1	7638.2	7638.2	7638.2	7638.2	7638.2
C6POLY	KG/HR	4311.98	4406.66	4406.66	4406.66	4406.66	4406.66
PROTINS	KG/HR	8336.5	8519.53	8519.53	8519.53	8519.53	8519.53
OIL	KG/HR	5749.31	5875.54	5875.54	5875.54	5875.54	5875.54
NFDS	KG/HR	12458.97	17599.8	17599.8	17599.8	17599.8	17599.8
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	5749.31	7928.44	7928.44	7928.44	7928.44	7928.44
MASSFRAC							
WATER		0.67	0.71	0.71	0.71	0.71	0.71
ETOH		0	0	0	0	0	0
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0.23	0.19	0.19	0.19	0.19	0.19
C5POLY		0.02	0.01	0.01	0.01	0.01	0.01
C6POLY		0.01	0.01	0.01	0.01	0.01	0.01
PROTINS		0.02	0.02	0.02	0.02	0.02	0.02
OIL		0.01	0.01	0.01	0.01	0.01	0.01
NFDS		0.03	0.03	0.03	0.03	0.03	0.03
XYLOSE		0	0	0	0	0	0
PROTSOL		0.01	0.02	0.02	0.02	0.02	0.02
Substream: MIXED							
Phase:		Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Component Mole Flow							
WATER	KMOL/HR	16644.23	20576.86	20576.86	20576.86	20576.86	20576.86
ETOH	KMOL/HR	29.24	29.85	29.85	29.85	29.85	29.85
CO2	KMOL/HR	1.11	1.11	1.11	1.11	1.11	1.11
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	0	0	0	0	0
C5POLY	KMOL/HR	0	0	0	0	0	0
C6POLY	KMOL/HR	0	0	0	0	0	0
PROTINS	KMOL/HR	0	0	0	0	0	0
OIL	KMOL/HR	0	0	0	0	0	0
NFDS	KMOL/HR	82.99	117.23	117.23	117.23	117.23	117.23
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	38.3	52.81	52.81	52.81	52.81	52.81
Component Mass Flow							
WATER	KG/HR	299845.9	370692.2	370692.2	370692.2	370692.2	370692.2
ETOH	KG/HR	1347.09	1375.04	1375.04	1375.04	1375.04	1375.04
CO2	KG/HR	49	49	49	49	49	49
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	0	0

		11LMASH	12MASH	13MASH	14MASH	16COOKED	17COOKED
From		**LIQUEFY**	**MIXBS**	**EM02C**	**EM03**	**EM02H**	**EM06H**
To		**EM01DUTY**	**EM02C**	**EM03**	**EM02H**	**EM06H**	**SACCHAR**
C5POLY	KG/HR	0	0	0	0	0	0
C6POLY	KG/HR	0	0	0	0	0	0
PROTINS	KG/HR	0	0	0	0	0	0
OIL	KG/HR	0	0	0	0	0	0
NFDS	KG/HR	12458.97	17599.8	17599.8	17599.8	17599.8	17599.8
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	5749.31	7928.44	7928.44	7928.44	7928.44	7928.44
Component Mass Fraction							
WATER		0.94	0.93	0.93	0.93	0.93	0.93
ETOH		0	0	0	0	0	0
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0	0
C5POLY		0	0	0	0	0	0
C6POLY		0	0	0	0	0	0
PROTINS		0	0	0	0	0	0
OIL		0	0	0	0	0	0
NFDS		0.04	0.04	0.04	0.04	0.04	0.04
XYLOSE		0	0	0	0	0	0
PROTSOL		0.02	0.02	0.02	0.02	0.02	0.02
Mole Flow	KMOL/HR	16795.87	20777.86	20777.86	20777.86	20777.86	20777.86
Mass Flow	KG/HR	319450.3	397644.5	397644.5	397644.5	397644.5	397644.5
Volume Flow	L/MIN	5346.42	6927.44	7025.31	7119.14	7019.02	6736.14
Temperature	C	45.05	86.09	98.56	110	97.78	60
Pressure	ATM	3.4	3.4	3.4	3.4	3.4	3.4
Vapor Fraction		0	0	0	0	0	0
Liquid Fraction		1	1	1	1	1	1
Solid Fraction		0	0	0	0	0	0
Molar Enthalpy	CAL/MOL	-69235.04	-68665.53	-68430.69	-68211.36	-68445.59	-69143.54
Mass Enthalpy	CAL/GM	-3640.2	-3587.94	-3575.67	-3564.2	-3576.44	-3612.91
Enthalpy Flow	CAL/SEC	-323017500	-396312000	-394956600	-393690700	-395042600	-399070900
Molar Entropy	CAL/MOL-K	-37.55	-35.33	-34.69	-34.12	-34.73	-36.7
Mass Entropy	CAL/GM-K	-1.97	-1.85	-1.81	-1.78	-1.81	-1.92
Molar Density	MOL/CC	0.05	0.05	0.05	0.05	0.05	0.05
Mass Density	GM/CC	1	0.96	0.94	0.93	0.94	0.98
Average Molecular Weight		19.02	19.14	19.14	19.14	19.14	19.14
Substream: CISOLID							
Component Mole Flow							
WATER	KMOL/HR	0	0	0	0	0	0
ETOH	KMOL/HR	0	0	0	0	0	0
CO2	KMOL/HR	0	0	0	0	0	0
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	620.53	620.66	620.66	620.66	620.66	620.66
C5POLY	KMOL/HR	56.57	57.81	57.81	57.81	57.81	57.81
C6POLY	KMOL/HR	26.59	27.18	27.18	27.18	27.18	27.18
PROTINS	KMOL/HR	63.1	64.49	64.49	64.49	64.49	64.49
OIL	KMOL/HR	43.52	44.47	44.47	44.47	44.47	44.47
NFDS	KMOL/HR	0	0	0	0	0	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	0	0	0

		11LMASH	12MASH	13MASH	14MASH	16COOKED	17COOKED
From		**LIQUEFY**	**MIXBS**	**EM02C**	**EM03**	**EM02H**	**EM06H**
To		**EM01DUTY**	**EM02C**	**EM03**	**EM02H**	**EM06H**	**SACCHAR**
Component Mass Flow							
WATER	KG/HR	0	0	0	0	0	0
ETOH	KG/HR	0	0	0	0	0	0
CO2	KG/HR	0	0	0	0	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	100612.9	100634.6	100634.6	100634.6	100634.6	100634.6
C5POLY	KG/HR	7474.1	7638.2	7638.2	7638.2	7638.2	7638.2
C6POLY	KG/HR	4311.98	4406.66	4406.66	4406.66	4406.66	4406.66
PROTINS	KG/HR	8336.5	8519.53	8519.53	8519.53	8519.53	8519.53
OIL	KG/HR	5749.31	5875.54	5875.54	5875.54	5875.54	5875.54
NFDS	KG/HR	0	0	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	0	0
Component Mass Fraction							
WATER		0	0	0	0	0	0
ETOH		0	0	0	0	0	0
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0.8	0.79	0.79	0.79	0.79	0.79
C5POLY		0.06	0.06	0.06	0.06	0.06	0.06
C6POLY		0.03	0.03	0.03	0.03	0.03	0.03
PROTINS		0.07	0.07	0.07	0.07	0.07	0.07
OIL		0.05	0.05	0.05	0.05	0.05	0.05
NFDS		0	0	0	0	0	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0	0	0	0	0
Mole Flow	KMOL/HR	810.31	814.61	814.61	814.61	814.61	814.61
Mass Flow	KG/HR	126484.8	127074.5	127074.5	127074.5	127074.5	127074.5
Volume Flow	L/MIN	1378.24	1384.67	1384.67	1384.67	1384.67	1384.67
Temperature	C	45.05	86.09	98.56	110	97.78	60
Pressure	ATM	3.4	3.4	3.4	3.4	3.4	3.4
Vapor Fraction		0	0	0	0	0	0
Liquid Fraction		0	0	0	0	0	0
Solid Fraction		1	1	1	1	1	1
Molar Enthalpy	CAL/MOL	-221660.1	-218461.5	-217454.5	-216496.6	-217519	-220440.9
Mass Enthalpy	CAL/GM	-1420.04	-1400.45	-1393.99	-1387.85	-1394.41	-1413.14
Enthalpy Flow	CAL/SEC	-49892730	-49433710	-49205860	-48989090	-49220440	-49881620
Molar Entropy	CAL/MOL-K	-741.89	-732.37	-729.61	-727.07	-729.78	-738.08
Mass Entropy	CAL/GM-K	-4.75	-4.69	-4.68	-4.66	-4.68	-4.73
Molar Density	MOL/CC	0.01	0.01	0.01	0.01	0.01	0.01
Mass Density	GM/CC	1.53	1.53	1.53	1.53	1.53	1.53
Average Molecular Weight		156.09	155.99	155.99	155.99	155.99	155.99

		19ENZYME	1GRAIN	20ACID	21MASH	22MASH	23MASH
From					**SACCHAR**	**EM04H**	**EM05**
To		**SACCHAR**	**MILL**	**SACCHAR**	**EM04H**	**EM05**	**FERMENT**
Substream: ALL							
Mass Flow	KG/HR	170.4	169606.2	336.46	525225.8	525225.8	525225.8
Mass Enthalpy	CAL/SEC	-179565.2	-85224910	-155430.1	-449726600	-451286600	-452490400
MASSFLOW							
WATER	KG/HR	170.4	25440.93	0	359793.2	359793.2	359793.2
ETOH	KG/HR	0	0	0	1375.04	1375.04	1375.04
CO2	KG/HR	0	0	0	49	49	49
GLUCOSE	KG/HR	0	0	0	110697.6	110697.6	110697.6
STARCH	KG/HR	0	100915.7	0	1006.35	1006.35	1006.35
C5POLY	KG/HR	0	7496.59	0	7638.2	7638.2	7638.2
C6POLY	KG/HR	0	4324.96	0	4406.66	4406.66	4406.66
PROTINS	KG/HR	0	8361.58	0	8519.53	8519.53	8519.53
OIL	KG/HR	0	5766.61	0	5875.54	5875.54	5875.54
NFDS	KG/HR	0	11533.22	336.46	17936.26	17936.26	17936.26
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	5766.61	0	7928.44	7928.44	7928.44
MASSFRAC							
WATER		1	0.15	0	0.69	0.69	0.69
ETOH		0	0	0	0	0	0
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0.21	0.21	0.21
STARCH		0	0.59	0	0	0	0
C5POLY		0	0.04	0	0.01	0.01	0.01
C6POLY		0	0.03	0	0.01	0.01	0.01
PROTINS		0	0.05	0	0.02	0.02	0.02
OIL		0	0.03	0	0.01	0.01	0.01
NFDS		0	0.07	1	0.03	0.03	0.03
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0.03	0	0.02	0.02	0.02
Substream: MIXED							
Phase:		Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Component Mole Flow							
WATER	KMOL/HR	9.46	1412.21	0	19971.87	19971.87	19971.87
ETOH	KMOL/HR	0	0	0	29.85	29.85	29.85
CO2	KMOL/HR	0	0	0	1.11	1.11	1.11
GLUCOSE	KMOL/HR	0	0	0	614.45	614.45	614.45
STARCH	KMOL/HR	0	0	0	0	0	0
C5POLY	KMOL/HR	0	0	0	0	0	0
C6POLY	KMOL/HR	0	0	0	0	0	0
PROTINS	KMOL/HR	0	0	0	0	0	0
OIL	KMOL/HR	0	0	0	0	0	0
NFDS	KMOL/HR	0	76.82	2.24	119.47	119.47	119.47
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	38.41	0	52.81	52.81	52.81
Component Mass Flow							
WATER	KG/HR	170.4	25440.93	0	359793.2	359793.2	359793.2
ETOH	KG/HR	0	0	0	1375.04	1375.04	1375.04
CO2	KG/HR	0	0	0	49	49	49
GLUCOSE	KG/HR	0	0	0	110697.6	110697.6	110697.6
STARCH	KG/HR	0	0	0	0	0	0

		19ENZYME	1GRAIN	20ACID	21MASH	22MASH	23MASH
From					**SACCHAR**	**EM04H**	**EM05**
To		**SACCHAR**	**MILL**	**SACCHAR**	**EM04H**	**EM05**	**FERMENT**
C5POLY	KG/HR	0	0	0	0	0	0
C6POLY	KG/HR	0	0	0	0	0	0
PROTINS	KG/HR	0	0	0	0	0	0
OIL	KG/HR	0	0	0	0	0	0
NFDS	KG/HR	0	11533.22	336.46	17936.26	17936.26	17936.26
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	5766.61	0	7928.44	7928.44	7928.44
Component Mass Fraction							
WATER		1	0.6	0	0.72	0.72	0.72
ETOH		0	0	0	0	0	0
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0.22	0.22	0.22
STARCH		0	0	0	0	0	0
C5POLY		0	0	0	0	0	0
C6POLY		0	0	0	0	0	0
PROTINS		0	0	0	0	0	0
OIL		0	0	0	0	0	0
NFDS		0	0.27	1	0.04	0.04	0.04
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0.13	0	0.02	0.02	0.02
Mole Flow	KMOL/HR	9.46	1527.44	2.24	20789.56	20789.56	20789.56
Mass Flow	KG/HR	170.4	42740.76	336.46	497779.5	497779.5	497779.5
Volume Flow	L/MIN	2.85	595.5	4.29	7713.72	7600.91	7515.82
Temperature	C	21.11	20	21.11	60	44.44	32.22
Pressure	ATM	1.02	1	1.02	2.72	2.72	2.72
Vapor Fraction		0	0	0	0	0	0
Liquid Fraction		1	1	1	1	1	1
Solid Fraction		0	0	0	0	0	0
Molar Enthalpy	CAL/MOL	-68343.04	-82040.6	-249672.3	-76039.65	-76308.69	-76516.51
Mass Enthalpy	CAL/GM	-3793.67	-2931.91	-1663.04	-3175.77	-3187	-3195.68
Enthalpy Flow	CAL/SEC	-179565.2	-34808920	-155430.1	-439119800	-440673500	-441873600
Molar Entropy	CAL/MOL-K	-39.13	-37.05	-18.98	-40.92	-41.75	-42.43
Mass Entropy	CAL/GM-K	-2.17	-1.32	-0.13	-1.71	-1.74	-1.77
Molar Density	MOL/CC	0.06	0.04	0.01	0.04	0.05	0.05
Mass Density	GM/CC	1	1.2	1.31	1.08	1.09	1.1
Average Molecular Weight		18.02	27.98	150.13	23.94	23.94	23.94
Substream: CISOLID							
Component Mole Flow							
WATER	KMOL/HR	0	0	0	0	0	0
ETOH	KMOL/HR	0	0	0	0	0	0
CO2	KMOL/HR	0	0	0	0	0	0
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	622.39	0	6.21	6.21	6.21
C5POLY	KMOL/HR	0	56.74	0	57.81	57.81	57.81
C6POLY	KMOL/HR	0	26.67	0	27.18	27.18	27.18
PROTINS	KMOL/HR	0	63.29	0	64.49	64.49	64.49
OIL	KMOL/HR	0	43.65	0	44.47	44.47	44.47
NFDS	KMOL/HR	0	0	0	0	0	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	0	0	0

		19ENZYME	1GRAIN	20ACID	21MASH	22MASH	23MASH
From					**SACCHAR**	**EM04H**	**EM05**
To		**SACCHAR**	**MILL**	**SACCHAR**	**EM04H**	**EM05**	**FERMENT**
Component Mass Flow							
WATER	KG/HR	0	0	0	0	0	0
ETOH	KG/HR	0	0	0	0	0	0
CO2	KG/HR	0	0	0	0	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	100915.7	0	1006.35	1006.35	1006.35
C5POLY	KG/HR	0	7496.59	0	7638.2	7638.2	7638.2
C6POLY	KG/HR	0	4324.96	0	4406.66	4406.66	4406.66
PROTINS	KG/HR	0	8361.58	0	8519.53	8519.53	8519.53
OIL	KG/HR	0	5766.61	0	5875.54	5875.54	5875.54
NFDS	KG/HR	0	0	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	0	0
Component Mass Fraction							
WATER			0		0	0	0
ETOH			0		0	0	0
CO2			0		0	0	0
GLUCOSE			0		0	0	0
STARCH			0.8		0.04	0.04	0.04
C5POLY			0.06		0.28	0.28	0.28
C6POLY			0.03		0.16	0.16	0.16
PROTINS			0.07		0.31	0.31	0.31
OIL			0.05		0.21	0.21	0.21
NFDS			0		0	0	0
XYLOSE			0		0	0	0
PROTSOL			0		0	0	0
Mole Flow	KMOL/HR	0	812.75	0	200.16	200.16	200.16
Mass Flow	KG/HR	0	126865.4	0	27446.28	27446.28	27446.28
Volume Flow	L/MIN	0	1382.39	0	299.13	299.13	299.13
Temperature	C		20		60	44.44	32.22
Pressure	ATM	1.02	1	1.02	2.72	2.72	2.72
Vapor Fraction			0		0	0	0
Liquid Fraction			0		0	0	0
Solid Fraction			1		1	1	1
Molar Enthalpy	CAL/MOL		-223312.9		-190771.2	-190886	-190952.5
Mass Enthalpy	CAL/GM		-1430.63		-1391.24	-1392.08	-1392.56
Enthalpy Flow	CAL/SEC		-50415990		-10606770	-10613160	-10616850
Molar Entropy	CAL/MOL-K		-747.3		-637.04	-637.39	-637.61
Mass Entropy	CAL/GM-K		-4.79		-4.65	-4.65	-4.65
Molar Density	MOL/CC		0.01		0.01	0.01	0.01
Mass Density	GM/CC		1.53		1.53	1.53	1.53
Average Molecular Weight			156.09		137.12	137.12	137.12

		24BEER	25BEER	27BEER	28BEER	29STILL	30BOV
From		**DUPLCOOL**	**EM04C**	**DEGAS**	**ED08C**	**BEERCOL**	**BEERCOL**
To		**EM04C**	**DEGAS**	**ED08C**	**BEERCOL**	**ED08H**	**RECTIFY**
Substream: ALL							
Mass Flow	KG/HR	472479	472479	467852.8	467852.8	374339.7	97386.3
Mass Enthalpy	CAL/SEC	-424443300	-422883200	-415534600	-413460900	-349019400	-56198990
MASSFLOW							
WATER	KG/HR	358902	358902	357191.8	357191.8	315320.4	43566.24
ETOH	KG/HR	54013.1	54013.1	51788.1	51788.1	173.45	53778.86
CO2	KG/HR	718	718	27.05	27.05	0	41.2
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	1006.35	1006.35	1006.35	1006.35	1006.35	0
C5POLY	KG/HR	7638.2	7638.2	7638.2	7638.2	7638.2	0
C6POLY	KG/HR	4406.66	4406.66	4406.66	4406.66	4406.66	0
PROTINS	KG/HR	8519.53	8519.53	8519.53	8519.53	8519.53	0
OIL	KG/HR	5875.54	5875.54	5875.54	5875.54	5875.54	0
NFDS	KG/HR	22052.03	22052.03	22052.03	22052.03	22052.03	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	9347.55	9347.55	9347.55	9347.55	9347.55	0
MASSFRAC							
WATER		0.76	0.76	0.76	0.76	0.84	0.45
ETOH		0.11	0.11	0.11	0.11	0	0.55
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0	0
C5POLY		0.02	0.02	0.02	0.02	0.02	0
C6POLY		0.01	0.01	0.01	0.01	0.01	0
PROTINS		0.02	0.02	0.02	0.02	0.02	0
OIL		0.01	0.01	0.01	0.01	0.02	0
NFDS		0.05	0.05	0.05	0.05	0.06	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0.02	0.02	0.02	0.02	0.02	0
Substream: MIXED							
Phase:		Liquid	Liquid	Liquid	Liquid	Liquid	Vapor
Component Mole Flow							
WATER	KMOL/HR	19922.4	19922.4	19827.46	19827.46	17503.22	2418.33
ETOH	KMOL/HR	1172.44	1172.44	1124.14	1124.14	3.76	1167.36
CO2	KMOL/HR	16.31	16.31	0.61	0.61	0	0.94
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	0	0	0	0	0
C5POLY	KMOL/HR	0	0	0	0	0	0
C6POLY	KMOL/HR	0	0	0	0	0	0
PROTINS	KMOL/HR	0	0	0	0	0	0
OIL	KMOL/HR	0	0	0	0	0	0
NFDS	KMOL/HR	146.89	146.89	146.89	146.89	146.89	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	62.26	62.26	62.26	62.26	62.26	0
Component Mass Flow							
WATER	KG/HR	358902	358902	357191.8	357191.8	315320.4	43566.24
ETOH	KG/HR	54013.1	54013.1	51788.1	51788.1	173.45	53778.86
CO2	KG/HR	718	718	27.05	27.05	0	41.2
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	0	0

		24BEER	25BEER	27BEER	28BEER	29STILL	30BOV
From		DUPLCOOL	EM04C	DEGAS	ED08C	BEERCOL	BEERCOL
To		EM04C	DEGAS	ED08C	BEERCOL	ED08H	RECTIFY
C5POLY	KG/HR	0	0	0	0	0	0
C6POLY	KG/HR	0	0	0	0	0	0
PROTINS	KG/HR	0	0	0	0	0	0
OIL	KG/HR	0	0	0	0	0	0
NFDS	KG/HR	22052.03	22052.03	22052.03	22052.03	22052.03	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	9347.55	9347.55	9347.55	9347.55	9347.55	0
Component Mass Fraction							
WATER		0.81	0.81	0.81	0.81	0.91	0.45
ETOH		0.12	0.12	0.12	0.12	0	0.55
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0	0
C5POLY		0	0	0	0	0	0
C6POLY		0	0	0	0	0	0
PROTINS		0	0	0	0	0	0
OIL		0	0	0	0	0	0
NFDS		0.05	0.05	0.05	0.05	0.06	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0.02	0.02	0.02	0.02	0.03	0
Mole Flow	KMOL/HR	21320.3	21320.3	21161.37	21161.37	17716.13	3586.62
Mass Flow	KG/HR	445032.7	445032.7	440406.5	440406.5	346893.5	97386.3
Volume Flow	L/MIN	7501.06	7614.42	7852.28	8020.06	6172.76	1203302
Temperature	C	32.22	46.39	83.89	101.42	115.22	102.44
Pressure	ATM	1.09	2.04	0.86	3.4	1.67	1.53
Vapor Fraction		0	0	0	0	0	1
Liquid Fraction		1	1	1	1	1	0
Solid Fraction		0	0	0	0	0	0
Molar Enthalpy	CAL/MOL	-69875.9	-69613.22	-68889.14	-68538.52	-68774.71	-56408.61
Mass Enthalpy	CAL/GM	-3347.56	-3334.98	-3310.1	-3293.25	-3512.38	-2077.46
Enthalpy Flow	CAL/SEC	-413826500	-412270800	-404941300	-402880300	-338450500	-56198990
Molar Entropy	CAL/MOL-K	-40.35	-39.5	-37.33	-36.39	-33.73	-21.55
Mass Entropy	CAL/GM-K	-1.93	-1.89	-1.79	-1.75	-1.72	-0.79
Molar Density	MOL/CC	0.05	0.05	0.04	0.04	0.05	0
Mass Density	GM/CC	0.99	0.97	0.93	0.92	0.94	0
Average Molecular Weight		20.87	20.87	20.81	20.81	19.58	27.15
Substream: CISOLID							
Component Mole Flow							
WATER	KMOL/HR	0	0	0	0	0	0
ETOH	KMOL/HR	0	0	0	0	0	0
CO2	KMOL/HR	0	0	0	0	0	0
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	6.21	6.21	6.21	6.21	6.21	0
C5POLY	KMOL/HR	57.81	57.81	57.81	57.81	57.81	0
C6POLY	KMOL/HR	27.18	27.18	27.18	27.18	27.18	0
PROTINS	KMOL/HR	64.49	64.49	64.49	64.49	64.49	0
OIL	KMOL/HR	44.47	44.47	44.47	44.47	44.47	0
NFDS	KMOL/HR	0	0	0	0	0	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	0	0	0

		24BEER	25BEER	27BEER	28BEER	29STILL	30BOV
From		**DUPLCOOL**	**EM04C**	**DEGAS**	**ED08C**	**BEERCOL**	**BEERCOL**
To		**EM04C**	**DEGAS**	**ED08C**	**BEERCOL**	**ED08H**	**RECTIFY**
Component Mass Flow							
WATER	KG/HR	0	0	0	0	0	0
ETOH	KG/HR	0	0	0	0	0	0
CO2	KG/HR	0	0	0	0	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	1006.35	1006.35	1006.35	1006.35	1006.35	0
C5POLY	KG/HR	7638.2	7638.2	7638.2	7638.2	7638.2	0
C6POLY	KG/HR	4406.66	4406.66	4406.66	4406.66	4406.66	0
PROTINS	KG/HR	8519.53	8519.53	8519.53	8519.53	8519.53	0
OIL	KG/HR	5875.54	5875.54	5875.54	5875.54	5875.54	0
NFDS	KG/HR	0	0	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	0	0
Component Mass Fraction							
WATER		0	0	0	0	0	
ETOH		0	0	0	0	0	
CO2		0	0	0	0	0	
GLUCOSE		0	0	0	0	0	
STARCH		0.04	0.04	0.04	0.04	0.04	
C5POLY		0.28	0.28	0.28	0.28	0.28	
C6POLY		0.16	0.16	0.16	0.16	0.16	
PROTINS		0.31	0.31	0.31	0.31	0.31	
OIL		0.21	0.21	0.21	0.21	0.21	
NFDS		0	0	0	0	0	
XYLOSE		0	0	0	0	0	
PROTSOL		0	0	0	0	0	
Mole Flow	KMOL/HR	200.16	200.16	200.16	200.16	200.16	0
Mass Flow	KG/HR	27446.28	27446.28	27446.28	27446.28	27446.28	0
Volume Flow	L/MIN	299.13	299.13	299.13	299.13	299.13	0
Temperature	C	32.22	46.39	83.89	101.42	115.22	
Pressure	ATM	1.09	2.04	0.86	3.4	1.67	
Vapor Fraction		0	0	0	0	0	
Liquid Fraction		0	0	0	0	0	
Solid Fraction		1	1	1	1	1	
Molar Enthalpy	CAL/MOL	-190952.5	-190873.5	-190529.1	-190300.7	-190090.5	
Mass Enthalpy	CAL/GM	-1392.56	-1391.99	-1389.47	-1387.81	-1386.28	
Enthalpy Flow	CAL/SEC	-10616850	-10612460	-10593310	-10580610	-10568930	
Molar Entropy	CAL/MOL-K	-637.61	-637.35	-636.34	-635.72	-635.16	
Mass Entropy	CAL/GM-K	-4.65	-4.65	-4.64	-4.64	-4.63	
Molar Density	MOL/CC	0.01	0.01	0.01	0.01	0.01	
Mass Density	GM/CC	1.53	1.53	1.53	1.53	1.53	
Average Molecular Weight		137.12	137.12	137.12	137.12	137.12	

		31ROV	3TRASH	40SB	41SHVAP	42ETOH	43ETOH
From		**RECTIFY**	**MILL**	**RECTIFY**	**ED03**	**MOLSIEVE**	**ED05H**
To		**ED03**		**PCST**	**MOLSIEVE**	**ED05H**	**ED06**
Substream: ALL							
Mass Flow	KG/HR	70624.32	508.82	43381.9	70624.32	54004.36	54004.36
Mass Enthalpy	CAL/SEC	-27005600	-255674.7	-44557430	-26772790	-17886710	-18073170
MASSFLOW							
WATER	KG/HR	6404.44	76.32	43360.2	6404.44	206.02	206.02
ETOH	KG/HR	64162.19	0	21.69	64162.19	53757.14	53757.14
CO2	KG/HR	57.68	0	0	57.68	41.2	41.2
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	302.75	0	0	0	0
C5POLY	KG/HR	0	22.49	0	0	0	0
C6POLY	KG/HR	0	12.97	0	0	0	0
PROTINS	KG/HR	0	25.08	0	0	0	0
OIL	KG/HR	0	17.3	0	0	0	0
NFDS	KG/HR	0	34.6	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	17.3	0	0	0	0
MASSFRAC							
WATER		0.09	0.15	1	0.09	0	0
ETOH		0.91	0	0	0.91	1	1
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0.59	0	0	0	0
C5POLY		0	0.04	0	0	0	0
C6POLY		0	0.03	0	0	0	0
PROTINS		0	0.05	0	0	0	0
OIL		0	0.03	0	0	0	0
NFDS		0	0.07	0	0	0	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0.03	0	0	0	0
Substream: MIXED							
Phase:		Vapor	Liquid	Mixed	Vapor	Vapor	Vapor
Component Mole Flow							
WATER	KMOL/HR	355.51	4.24	2406.9	355.51	11.44	11.44
ETOH	KMOL/HR	1392.74	0	0.47	1392.74	1166.88	1166.88
CO2	KMOL/HR	1.31	0	0	1.31	0.94	0.94
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	0	0	0	0	0
C5POLY	KMOL/HR	0	0	0	0	0	0
C6POLY	KMOL/HR	0	0	0	0	0	0
PROTINS	KMOL/HR	0	0	0	0	0	0
OIL	KMOL/HR	0	0	0	0	0	0
NFDS	KMOL/HR	0	0.23	0	0	0	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0.12	0	0	0	0
Component Mass Flow							
WATER	KG/HR	6404.44	76.32	43360.2	6404.44	206.02	206.02
ETOH	KG/HR	64162.19	0	21.69	64162.19	53757.14	53757.14
CO2	KG/HR	57.68	0	0	57.68	41.2	41.2
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	0	0

		31ROV	3TRASH	40SB	41SHVAP	42ETOH	43ETOH
From		**RECTIFY**	**MILL**	**RECTIFY**	**ED03**	**MOLSIEVE**	**ED05H**
To		**ED03**		**PCST**	**MOLSIEVE**	**ED05H**	**ED06**
C5POLY	KG/HR	0	0	0	0	0	0
C6POLY	KG/HR	0	0	0	0	0	0
PROTINS	KG/HR	0	0	0	0	0	0
OIL	KG/HR	0	0	0	0	0	0
NFDS	KG/HR	0	34.6	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	17.3	0	0	0	0
Component Mass Fraction							
WATER		0.09	0.6	1	0.09	0	0
ETOH		0.91	0	0	0.91	1	1
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0	0
C5POLY		0	0	0	0	0	0
C6POLY		0	0	0	0	0	0
PROTINS		0	0	0	0	0	0
OIL		0	0	0	0	0	0
NFDS		0	0.27	0	0	0	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0.13	0	0	0	0
Mole Flow	KMOL/HR	1749.56	4.58	2407.36	1749.56	1179.26	1179.26
Mass Flow	KG/HR	70624.32	128.22	43381.9	70624.32	54004.36	54004.36
Volume Flow	L/MIN	631998.4	1.79	801.6	692052.4	491342.5	576863
Temperature	C	86.32	20	114.36	115.56	115.56	84.54
Pressure	ATM	1.36	1	1.63	1.34	1.28	1
Vapor Fraction		1	0	0	1	1	1
Liquid Fraction		0	1	1	0	0	0
Solid Fraction		0	0	0	0	0	0
Molar Enthalpy	CAL/MOL	-55568.41	-82040.6	-66631.67	-55089.37	-54604.07	-55173.29
Mass Enthalpy	CAL/GM	-1376.58	-2931.91	-3697.55	-1364.71	-1192.35	-1204.78
Enthalpy Flow	CAL/SEC	-27005600	-104426.8	-44557430	-26772790	-17886710	-18073170
Molar Entropy	CAL/MOL-K	-41.4	-37.05	-34.11	-40.09	-48.68	-49.72
Mass Entropy	CAL/GM-K	-1.03	-1.32	-1.89	-0.99	-1.06	-1.09
Molar Density	MOL/CC	0	0.04	0.05	0	0	0
Mass Density	GM/CC	0	1.2	0.9	0	0	0
Average Molecular Weight		40.37	27.98	18.02	40.37	45.8	45.8
Substream: CISOLID							
Component Mole Flow							
WATER	KMOL/HR	0	0	0	0	0	0
ETOH	KMOL/HR	0	0	0	0	0	0
CO2	KMOL/HR	0	0	0	0	0	0
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	1.87	0	0	0	0
C5POLY	KMOL/HR	0	0.17	0	0	0	0
C6POLY	KMOL/HR	0	0.08	0	0	0	0
PROTINS	KMOL/HR	0	0.19	0	0	0	0
OIL	KMOL/HR	0	0.13	0	0	0	0
NFDS	KMOL/HR	0	0	0	0	0	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	0	0	0

		31ROV	3TRASH	40SB	41SHVAP	42ETOH	43ETOH
From		**RECTIFY**	**MILL**	**RECTIFY**	**ED03**	**MOLSIEVE**	**ED05H**
To		**ED03**		**PCST**	**MOLSIEVE**	**ED05H**	**ED06**
Component Mass Flow							
WATER	KG/HR	0	0	0	0	0	0
ETOH	KG/HR	0	0	0	0	0	0
CO2	KG/HR	0	0	0	0	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	302.75	0	0	0	0
C5POLY	KG/HR	0	22.49	0	0	0	0
C6POLY	KG/HR	0	12.97	0	0	0	0
PROTINS	KG/HR	0	25.08	0	0	0	0
OIL	KG/HR	0	17.3	0	0	0	0
NFDS	KG/HR	0	0	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	0	0
Component Mass Fraction							
WATER			0				
ETOH			0				
CO2			0				
GLUCOSE			0				
STARCH			0.8				
C5POLY			0.06				
C6POLY			0.03				
PROTINS			0.07				
OIL			0.05				
NFDS			0				
XYLOSE			0				
PROTSOL			0				
Mole Flow	KMOL/HR	0	2.44	0	0	0	0
Mass Flow	KG/HR	0	380.6	0	0	0	0
Volume Flow	L/MIN	0	4.15	0	0	0	0
Temperature	C		20				
Pressure	ATM		1	1.63	1.34	1.28	1
Vapor Fraction			0				
Liquid Fraction			0				
Solid Fraction			1				
Molar Enthalpy	CAL/MOL		-223312.9				
Mass Enthalpy	CAL/GM		-1430.63				
Enthalpy Flow	CAL/SEC		-151248				
Molar Entropy	CAL/MOL-K		-747.3				
Mass Entropy	CAL/GM-K		-4.79				
Molar Density	MOL/CC		0.01				
Mass Density	GM/CC		1.53				
Average Molecular Weight			156.09				

		44ETOH	45REGEN	46REGEN	47REGEN	4GRAIN	52WS
From		**ED06**	**MOLSIEVE**	**ED04**	**ED05C**	**MILL**	**ED08H**
To		**SEPETH**	**ED04**	**ED05C**	**RECTIFY**	**LIQUEFY**	**PRE-EVAP**
Substream: ALL							
Mass Flow	KG/HR	54004.36	16619.96	16619.96	16619.91	169097.4	374339.7
Mass Enthalpy	CAL/SEC	-21634770	-8886086	-10674520	-10488030	-84828380	-351093200
MASSFLOW							
WATER	KG/HR	206.02	6198.43	6198.43	6198.41	25364.6	315320.4
ETOH	KG/HR	53757.14	10405.05	10405.05	10405.03	0	173.45
CO2	KG/HR	41.2	16.48	16.48	16.48	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	100612.9	1006.35
C5POLY	KG/HR	0	0	0	0	7474.1	7638.2
C6POLY	KG/HR	0	0	0	0	4311.98	4406.66
PROTINS	KG/HR	0	0	0	0	8336.5	8519.53
OIL	KG/HR	0	0	0	0	5749.31	5875.54
NFDS	KG/HR	0	0	0	0	11498.62	22052.03
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	5749.31	9347.55
MASSFRAC							
WATER		0	0.37	0.37	0.37	0.15	0.84
ETOH		1	0.63	0.63	0.63	0	0
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0.59	0
C5POLY		0	0	0	0	0.04	0.02
C6POLY		0	0	0	0	0.03	0.01
PROTINS		0	0	0	0	0.05	0.02
OIL		0	0	0	0	0.03	0.02
NFDS		0	0	0	0	0.07	0.06
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0	0	0	0.03	0.02
Substream: MIXED							
Phase:		Liquid	Vapor	Liquid	Liquid	Liquid	Liquid
Component Mole Flow							
WATER	KMOL/HR	11.44	344.07	344.07	344.07	1407.97	17503.22
ETOH	KMOL/HR	1166.88	225.86	225.86	225.86	0	3.76
CO2	KMOL/HR	0.94	0.37	0.37	0.37	0	0
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	0	0	0	0	0
C5POLY	KMOL/HR	0	0	0	0	0	0
C6POLY	KMOL/HR	0	0	0	0	0	0
PROTINS	KMOL/HR	0	0	0	0	0	0
OIL	KMOL/HR	0	0	0	0	0	0
NFDS	KMOL/HR	0	0	0	0	76.59	146.89
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	0	38.3	62.26
Component Mass Flow							
WATER	KG/HR	206.02	6198.43	6198.43	6198.41	25364.6	315320.4
ETOH	KG/HR	53757.14	10405.05	10405.05	10405.03	0	173.45
CO2	KG/HR	41.2	16.48	16.48	16.48	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	0	0

		44ETOH	45REGEN	46REGEN	47REGEN	4GRAIN	52WS
From		**ED06**	**MOLSIEVE**	**ED04**	**ED05C**	**MILL**	**ED08H**
To		**SEPETH**	**ED04**	**ED05C**	**RECTIFY**	**LIQUEFY**	**PRE-EVAP**
C5POLY	KG/HR	0	0	0	0	0	0
C6POLY	KG/HR	0	0	0	0	0	0
PROTINS	KG/HR	0	0	0	0	0	0
OIL	KG/HR	0	0	0	0	0	0
NFDS	KG/HR	0	0	0	0	11498.62	22052.03
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	5749.31	9347.55
Component Mass Fraction							
WATER		0	0.37	0.37	0.37	0.6	0.91
ETOH		1	0.63	0.63	0.63	0	0
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0	0
C5POLY		0	0	0	0	0	0
C6POLY		0	0	0	0	0	0
PROTINS		0	0	0	0	0	0
OIL		0	0	0	0	0	0
NFDS		0	0	0	0	0.27	0.06
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0	0	0	0.13	0.03
Mole Flow	KMOL/HR	1179.26	570.3	570.3	570.3	1522.86	17716.13
Mass Flow	KG/HR	54004.36	16619.96	16619.96	16619.91	42612.54	346893.5
Volume Flow	L/MIN	1168.58	2970243	324.21	345.66	597.21	6018.89
Temperature	C	37.78	115.56	35	80.08	26.67	93.33
Pressure	ATM	1.26	0.1	1.5	1.53	1	2.72
Vapor Fraction		0	1	0	0	0	0
Liquid Fraction		1	0	1	1	1	1
Solid Fraction		0	0	0	0	0	0
Molar Enthalpy	CAL/MOL	-66046.06	-56092.86	-67382.23	-66205.22	-81933.39	-69192.48
Mass Enthalpy	CAL/GM	-1442.2	-1924.79	-2312.18	-2271.79	-2928.08	-3533.72
Enthalpy Flow	CAL/SEC	-21634770	-8886086	-10674520	-10488030	-34659140	-340506400
Molar Entropy	CAL/MOL-K	-80.8	-18.53	-54.9	-51.4	-36.67	-34.82
Mass Entropy	CAL/GM-K	-1.76	-0.64	-1.88	-1.76	-1.31	-1.78
Molar Density	MOL/CC	0.02	0	0.03	0.03	0.04	0.05
Mass Density	GM/CC	0.77	0	0.85	0.8	1.19	0.96
Average Molecular Weight		45.8	29.14	29.14	29.14	27.98	19.58
Substream: CISOLID							
Component Mole Flow							
WATER	KMOL/HR	0	0	0	0	0	0
ETOH	KMOL/HR	0	0	0	0	0	0
CO2	KMOL/HR	0	0	0	0	0	0
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	0	0	0	620.53	6.21
C5POLY	KMOL/HR	0	0	0	0	56.57	57.81
C6POLY	KMOL/HR	0	0	0	0	26.59	27.18
PROTINS	KMOL/HR	0	0	0	0	63.1	64.49
OIL	KMOL/HR	0	0	0	0	43.52	44.47
NFDS	KMOL/HR	0	0	0	0	0	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	0	0	0

		44ETOH	45REGEN	46REGEN	47REGEN	4GRAIN	52WS
From		**ED06**	**MOLSIEVE**	**ED04**	**ED05C**	**MILL**	**ED08H**
To		**SEPETH**	**ED04**	**ED05C**	**RECTIFY**	**LIQUEFY**	**PRE-EVAP**
Component Mass Flow							
WATER	KG/HR	0	0	0	0	0	0
ETOH	KG/HR	0	0	0	0	0	0
CO2	KG/HR	0	0	0	0	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	100612.9	1006.35
C5POLY	KG/HR	0	0	0	0	7474.1	7638.2
C6POLY	KG/HR	0	0	0	0	4311.98	4406.66
PROTINS	KG/HR	0	0	0	0	8336.5	8519.53
OIL	KG/HR	0	0	0	0	5749.31	5875.54
NFDS	KG/HR	0	0	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	0	0
Component Mass Fraction							
WATER						0	0
ETOH						0	0
CO2						0	0
GLUCOSE						0	0
STARCH						0.8	0.04
C5POLY						0.06	0.28
C6POLY						0.03	0.16
PROTINS						0.07	0.31
OIL						0.05	0.21
NFDS						0	0
XYLOSE						0	0
PROTSOL						0	0
Mole Flow	KMOL/HR	0	0	0	0	810.31	200.16
Mass Flow	KG/HR	0	0	0	0	126484.8	27446.28
Volume Flow	L/MIN	0	0	0	0	1378.24	299.13
Temperature	C					26.67	93.33
Pressure	ATM	1.26	0.1	1.5		1	2.72
Vapor Fraction						0	0
Liquid Fraction						0	0
Solid Fraction						1	1
Molar Enthalpy	CAL/MOL					-222888.5	-190411.3
Mass Enthalpy	CAL/GM					-1427.91	-1388.62
Enthalpy Flow	CAL/SEC					-50169230	-10586760
Molar Entropy	CAL/MOL-K					-745.87	-636.01
Mass Entropy	CAL/GM-K					-4.78	-4.64
Molar Density	MOL/CC					0.01	0.01
Mass Density	GM/CC					1.53	1.53
Average Molecular Weight						156.09	137.12

		53PEWS	55TS	56WG	58TS	59BS	60S
From		**PRE-EVAP**	**CENTRIF**	**CENTRIF**	**TSSURGE**	**TSSURGE**	**EVAP6**
To		**CENTRIF**	**TSSURGE**	**MIXDDGS**	**EVAP6**	**MIXBS**	**MIXDDGS**
Substream: ALL							
Mass Flow	KG/HR	362866.1	293366.9	69499.19	214583	78783.85	39171.41
Mass Enthalpy	CAL/SEC	-340680800	-287386500	-53294250	-210208700	-77177820	-28040270
MASSFLOW							
WATER	KG/HR	303900.4	263809.8	40090.56	192963.5	70846.3	17627.15
ETOH	KG/HR	119.86	104.05	15.81	76.11	27.94	0.85
CO2	KG/HR	0	0	0	0	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	1006.35	80.51	925.84	58.89	21.62	58.89
C5POLY	KG/HR	7638.2	611.06	7027.15	446.96	164.1	446.96
C6POLY	KG/HR	4406.66	352.53	4054.12	257.86	94.67	257.86
PROTINS	KG/HR	8519.53	681.56	7837.97	498.53	183.03	498.53
OIL	KG/HR	5875.54	470.04	5405.5	343.81	126.23	343.81
NFDS	KG/HR	22052.03	19142.92	2909.11	14002.08	5140.82	14002.08
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	9347.55	8114.42	1233.13	5935.29	2179.13	5935.29
MASSFRAC							
WATER		0.84	0.9	0.58	0.9	0.9	0.45
ETOH		0	0	0	0	0	0
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0.01	0	0	0
C5POLY		0.02	0	0.1	0	0	0.01
C6POLY		0.01	0	0.06	0	0	0.01
PROTINS		0.02	0	0.11	0	0	0.01
OIL		0.02	0	0.08	0	0	0.01
NFDS		0.06	0.07	0.04	0.07	0.07	0.36
XYLOSE		0	0	0	0	0	0
PROTSOL		0.03	0.03	0.02	0.03	0.03	0.15
Substream: MIXED							
Phase:		Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Component Mole Flow							
WATER	KMOL/HR	16869.3	14643.9	2225.4	10711.27	3932.63	978.47
ETOH	KMOL/HR	2.6	2.26	0.34	1.65	0.61	0.02
CO2	KMOL/HR	0	0	0	0	0	0
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	0	0	0	0	0
C5POLY	KMOL/HR	0	0	0	0	0	0
C6POLY	KMOL/HR	0	0	0	0	0	0
PROTINS	KMOL/HR	0	0	0	0	0	0
OIL	KMOL/HR	0	0	0	0	0	0
NFDS	KMOL/HR	146.89	127.51	19.38	93.27	34.24	93.27
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	62.26	54.05	8.21	39.53	14.51	39.53
Component Mass Flow							
WATER	KG/HR	303900.4	263809.8	40090.56	192963.5	70846.3	17627.15
ETOH	KG/HR	119.86	104.05	15.81	76.11	27.94	0.85
CO2	KG/HR	0	0	0	0	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	0	0

		53PEWS	55TS	56WG	58TS	59BS	60S
From		**PRE-EVAP**	**CENTRIF**	**CENTRIF**	**TSSURGE**	**TSSURGE**	**EVAP6**
To		**CENTRIF**	**TSSURGE**	**MIXDDGS**	**EVAP6**	**MIXBS**	**MIXDDGS**
C5POLY	KG/HR	0	0	0	0	0	0
C6POLY	KG/HR	0	0	0	0	0	0
PROTINS	KG/HR	0	0	0	0	0	0
OIL	KG/HR	0	0	0	0	0	0
NFDS	KG/HR	22052.03	19142.92	2909.11	14002.08	5140.82	14002.08
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	9347.55	8114.42	1233.13	5935.29	2179.13	5935.29
Component Mass Fraction							
WATER		0.91	0.91	0.91	0.91	0.91	0.47
ETOH		0	0	0	0	0	0
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0	0
C5POLY		0	0	0	0	0	0
C6POLY		0	0	0	0	0	0
PROTINS		0	0	0	0	0	0
OIL		0	0	0	0	0	0
NFDS		0.07	0.07	0.07	0.07	0.07	0.37
XYLOSE		0	0	0	0	0	0
PROTSOL		0.03	0.03	0.03	0.03	0.03	0.16
Mole Flow	KMOL/HR	17081.05	14827.71	2253.33	10845.72	3981.99	1111.29
Mass Flow	KG/HR	335419.8	291171.2	44248.61	212977	78194.19	37565.36
Volume Flow	L/MIN	5710.83	4957.45	753.37	3626.13	1331.33	525.98
Temperature	C	77.39	77.39	77.39	77.39	77.39	94.89
Pressure	ATM	0.42	0.42	0.42	0.42	0.42	0.73
Vapor Fraction		0	0	0	0	0	0
Liquid Fraction		1	1	1	1	1	1
Solid Fraction		0	0	0	0	0	0
Molar Enthalpy	CAL/MOL	-69568.35	-69568.35	-69568.35	-69568.35	-69568.32	-88829.25
Mass Enthalpy	CAL/GM	-3542.72	-3542.72	-3542.72	-3542.72	-3542.72	-2627.82
Enthalpy Flow	CAL/SEC	-330083400	-286538800	-43544630	-209588600	-76950140	-27420840
Molar Entropy	CAL/MOL-K	-35.62	-35.62	-35.62	-35.62	-35.62	-32.16
Mass Entropy	CAL/GM-K	-1.81	-1.81	-1.81	-1.81	-1.81	-0.95
Molar Density	MOL/CC	0.05	0.05	0.05	0.05	0.05	0.04
Mass Density	GM/CC	0.98	0.98	0.98	0.98	0.98	1.19
Average Molecular Weight		19.64	19.64	19.64	19.64	19.64	33.8
Substream: CISOLID							
Component Mole Flow							
WATER	KMOL/HR	0	0	0	0	0	0
ETOH	KMOL/HR	0	0	0	0	0	0
CO2	KMOL/HR	0	0	0	0	0	0
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	6.21	0.5	5.71	0.36	0.13	0.36
C5POLY	KMOL/HR	57.81	4.63	53.19	3.38	1.24	3.38
C6POLY	KMOL/HR	27.18	2.17	25	1.59	0.58	1.59
PROTINS	KMOL/HR	64.49	5.16	59.33	3.77	1.39	3.77
OIL	KMOL/HR	44.47	3.56	40.92	2.6	0.96	2.6
NFDS	KMOL/HR	0	0	0	0	0	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	0	0	0

		53PEWS	55TS	56WG	58TS	59BS	60S
From		**PRE-EVAP**	**CENTRIF**	**CENTRIF**	**TSSURGE**	**TSSURGE**	**EVAP6**
To		**CENTRIF**	**TSSURGE**	**MIXDDGS**	**EVAP6**	**MIXBS**	**MIXDDGS**
Component Mass Flow							
WATER	KG/HR	0	0	0	0	0	0
ETOH	KG/HR	0	0	0	0	0	0
CO2	KG/HR	0	0	0	0	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	1006.35	80.51	925.84	58.89	21.62	58.89
C5POLY	KG/HR	7638.2	611.06	7027.15	446.96	164.1	446.96
C6POLY	KG/HR	4406.66	352.53	4054.12	257.86	94.67	257.86
PROTINS	KG/HR	8519.53	681.56	7837.97	498.53	183.03	498.53
OIL	KG/HR	5875.54	470.04	5405.5	343.81	126.23	343.81
NFDS	KG/HR	0	0	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	0	0
Component Mass Fraction							
WATER		0	0	0	0	0	0
ETOH		0	0	0	0	0	0
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0.04	0.04	0.04	0.04	0.04	0.04
C5POLY		0.28	0.28	0.28	0.28	0.28	0.28
C6POLY		0.16	0.16	0.16	0.16	0.16	0.16
PROTINS		0.31	0.31	0.31	0.31	0.31	0.31
OIL		0.21	0.21	0.21	0.21	0.21	0.21
NFDS		0	0	0	0	0	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0	0	0	0	0
Mole Flow	KMOL/HR	200.16	16.01	184.15	11.71	4.3	11.71
Mass Flow	KG/HR	27446.28	2195.7	25250.58	1606.05	589.66	1606.05
Volume Flow	L/MIN	299.13	23.93	275.2	17.5	6.43	17.5
Temperature	C	77.39	77.39	77.39	77.39	77.39	94.89
Pressure	ATM	0.42	0.42	0.42	0.42	0.42	0.73
Vapor Fraction		0	0	0	0	0	0
Liquid Fraction		0	0	0	0	0	0
Solid Fraction		1	1	1	1	1	1
Molar Enthalpy	CAL/MOL	-190602.8	-190602.8	-190602.8	-190602.8	-190602.8	-190390.7
Mass Enthalpy	CAL/GM	-1390.01	-1390.01	-1390.01	-1390.01	-1390.01	-1388.47
Enthalpy Flow	CAL/SEC	-10597410	-847793	-9749619	-620117.6	-227675.3	-619427.6
Molar Entropy	CAL/MOL-K	-636.55	-636.55	-636.55	-636.55	-636.55	-635.96
Mass Entropy	CAL/GM-K	-4.64	-4.64	-4.64	-4.64	-4.64	-4.64
Molar Density	MOL/CC	0.01	0.01	0.01	0.01	0.01	0.01
Mass Density	GM/CC	1.53	1.53	1.53	1.53	1.53	1.53
Average Molecular Weight		137.12	137.12	137.12	137.12	137.12	137.12

		64EC	65DDGS	66VENT	68CO2	6CA	72CO2
From		**MIXCON**	**DRYDDGS**	**DRYDDGS**	**DUPLCO2**		**DEGAS**
To		**PCST**			**SCRUBBER**	**LIQUEFY**	**ED07**
Substream: ALL							
Mass Flow	KG/HR	186885.3	55975.36	52695.23	52779.79	201.03	4626.19
Mass Enthalpy	CAL/SEC	-195120000	-26663580	-46432010	-31290910	-92868.23	-2659133
MASSFLOW							
WATER	KG/HR	186756.4	5038.84	52678.88	922.97	0	1710.24
ETOH	KG/HR	128.85	0.3	16.35	1145.78	0	2225
CO2	KG/HR	0	0	0	50711.04	0	690.95
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	984.73	0	0	0	0
C5POLY	KG/HR	0	7474.1	0	0	0	0
C6POLY	KG/HR	0	4311.98	0	0	0	0
PROTINS	KG/HR	0	8336.5	0	0	0	0
OIL	KG/HR	0	5749.31	0	0	0	0
NFDS	KG/HR	0	16911.18	0	0	201.03	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	7168.42	0	0	0	0
MASSFRAC							
WATER		1	0.09	1	0.02	0	0.37
ETOH		0	0	0	0.02	0	0.48
CO2		0	0	0	0.96	0	0.15
GLUCOSE		0	0	0	0	0	0
STARCH		0	0.02	0	0	0	0
C5POLY		0	0.13	0	0	0	0
C6POLY		0	0.08	0	0	0	0
PROTINS		0	0.15	0	0	0	0
OIL		0	0.1	0	0	0	0
NFDS		0	0.3	0	0	1	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0.13	0	0	0	0
Substream: MIXED							
Phase:		Liquid	Liquid	Vapor	Vapor	Liquid	Vapor
Component Mole Flow							
WATER	KMOL/HR	10366.72	279.7	2924.17	51.23	0	94.93
ETOH	KMOL/HR	2.8	0.01	0.35	24.87	0	48.3
CO2	KMOL/HR	0	0	0	1152.26	0	15.7
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	0	0	0	0	0
C5POLY	KMOL/HR	0	0	0	0	0	0
C6POLY	KMOL/HR	0	0	0	0	0	0
PROTINS	KMOL/HR	0	0	0	0	0	0
OIL	KMOL/HR	0	0	0	0	0	0
NFDS	KMOL/HR	0	112.64	0	0	1.34	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	47.75	0	0	0	0
Component Mass Flow							
WATER	KG/HR	186756.4	5038.84	52678.88	922.97	0	1710.24
ETOH	KG/HR	128.85	0.3	16.35	1145.78	0	2225
CO2	KG/HR	0	0	0	50711.04	0	690.95
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	0	0

		64EC	65DDGS	66VENT	68CO2	6CA	72CO2
From		MIXCON	DRYDDGS	DRYDDGS	DUPLCO2		DEGAS
To		PCST			SCRUBBER	LIQUEFY	ED07
C5POLY	KG/HR	0	0	0	0	0	0
C6POLY	KG/HR	0	0	0	0	0	0
PROTINS	KG/HR	0	0	0	0	0	0
OIL	KG/HR	0	0	0	0	0	0
NFDS	KG/HR	0	16911.18	0	0	201.03	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	7168.42	0	0	0	0
Component Mass Fraction							
WATER		1	0.17	1	0.02	0	0.37
ETOH		0	0	0	0.02	0	0.48
CO2		0	0	0	0.96	0	0.15
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0	0
C5POLY		0	0	0	0	0	0
C6POLY		0	0	0	0	0	0
PROTINS		0	0	0	0	0	0
OIL		0	0	0	0	0	0
NFDS		0	0.58	0	0	1	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0.25	0	0	0	0
Mole Flow	KMOL/HR	10369.52	440.1	2924.52	1228.37	1.34	158.93
Mass Flow	KG/HR	186885.3	29118.74	52695.23	52779.79	201.03	4626.19
Volume Flow	L/MIN	3233.76	359.99	2035945	471188.2	2.57	89802.29
Temperature	C	55.28	104.44	104.44	32.22	21.11	83.89
Pressure	ATM	1.02	0.74	0.74	1.09	1	0.86
Vapor Fraction		0	0	1	1	0	1
Liquid Fraction		1	1	0	0	1	0
Solid Fraction		0	0	0	0	0	0
Molar Enthalpy	CAL/MOL	-67740.08	-133436.7	-57156.42	-91704.96	-249672.3	-60232.82
Mass Enthalpy	CAL/GM	-3758.63	-2016.76	-3172.11	-2134.29	-1663.04	-2069.28
Enthalpy Flow	CAL/SEC	-195120000	-16312670	-46432010	-31290910	-92868.23	-2659133
Molar Entropy	CAL/MOL-K	-37.17	-26.75	-8.1	-0.28	-18.98	-18.44
Mass Entropy	CAL/GM-K	-2.06	-0.4	-0.45	-0.01	-0.13	-0.63
Molar Density	MOL/CC	0.05	0.02	0	0	0.01	0
Mass Density	GM/CC	0.96	1.35	0	0	1.31	0
Average Molecular Weight		18.02	66.16	18.02	42.97	150.13	29.11
Substream: CISOLID							
Component Mole Flow							
WATER	KMOL/HR	0	0	0	0	0	0
ETOH	KMOL/HR	0	0	0	0	0	0
CO2	KMOL/HR	0	0	0	0	0	0
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	6.07	0	0	0	0
C5POLY	KMOL/HR	0	56.57	0	0	0	0
C6POLY	KMOL/HR	0	26.59	0	0	0	0
PROTINS	KMOL/HR	0	63.1	0	0	0	0
OIL	KMOL/HR	0	43.52	0	0	0	0
NFDS	KMOL/HR	0	0	0	0	0	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	0	0	0

		64EC	65DDGS	66VENT	68CO2	6CA	72CO2
From		**MIXCON**	**DRYDDGS**	**DRYDDGS**	**DUPLCO2**		**DEGAS**
To		**PCST**			**SCRUBBER**	**LIQUEFY**	**ED07**
Component Mass Flow							
WATER	KG/HR	0	0	0	0	0	0
ETOH	KG/HR	0	0	0	0	0	0
CO2	KG/HR	0	0	0	0	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	984.73	0	0	0	0
C5POLY	KG/HR	0	7474.1	0	0	0	0
C6POLY	KG/HR	0	4311.98	0	0	0	0
PROTINS	KG/HR	0	8336.5	0	0	0	0
OIL	KG/HR	0	5749.31	0	0	0	0
NFDS	KG/HR	0	0	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	0	0
Component Mass Fraction							
WATER			0				
ETOH			0				
CO2			0				
GLUCOSE			0				
STARCH			0.04				
C5POLY			0.28				
C6POLY			0.16				
PROTINS			0.31				
OIL			0.21				
NFDS			0				
XYLOSE			0				
PROTSOL			0				
Mole Flow	KMOL/HR	0	195.86	0	0	0	0
Mass Flow	KG/HR	0	26856.62	0	0	0	0
Volume Flow	L/MIN	0	292.71	0	0	0	0
Temperature	C		104.44				
Pressure	ATM	1.02	0.74	0.74	1.09	1	0.86
Vapor Fraction			0				
Liquid Fraction			0				
Solid Fraction			1				
Molar Enthalpy	CAL/MOL		-190256.9				
Mass Enthalpy	CAL/GM		-1387.49				
Enthalpy Flow	CAL/SEC		-10350910				
Molar Entropy	CAL/MOL-K		-635.6				
Mass Entropy	CAL/GM-K		-4.64				
Molar Density	MOL/CC		0.01				
Mass Density	GM/CC		1.53				
Average Molecular Weight			137.12				

		73CO2	74CO2	75SW	7ENZYME	85PC	86HPC
From		**ED07**	**SCRUBBER**	**SCRUBBER**		**SPLITPC**	**DUPLHPC**
To		**SCRUBBER**		**PCST**	**LIQUEFY**	**DUPLHPC**	**LIQUEFY**
Substream: ALL							
Mass Flow	KG/HR	752.91	51859.17	37558.4	117.97	267725.9	267725.9
Mass Enthalpy	CAL/SEC	-435397.1	-30947690	-38673360	-124319.1	-278247200	-278247200
MASSFLOW							
WATER	KG/HR	15.32	510.84	36312.32	117.97	266329.8	266329.8
ETOH	KG/HR	60.8	9.52	1197.06	0	1347.1	1347.09
CO2	KG/HR	676.8	51338.82	49.02	0	49	49
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	0	0
C5POLY	KG/HR	0	0	0	0	0	0
C6POLY	KG/HR	0	0	0	0	0	0
PROTINS	KG/HR	0	0	0	0	0	0
OIL	KG/HR	0	0	0	0	0	0
NFDS	KG/HR	0	0	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	0	0
MASSFRAC							
WATER		0.02	0.01	0.97	1	0.99	0.99
ETOH		0.08	0	0.03	0	0.01	0.01
CO2		0.9	0.99	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0	0
C5POLY		0	0	0	0	0	0
C6POLY		0	0	0	0	0	0
PROTINS		0	0	0	0	0	0
OIL		0	0	0	0	0	0
NFDS		0	0	0	0	0	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0	0	0	0	0
Substream: MIXED							
Phase:		Vapor	Vapor	Liquid	Liquid	Liquid	Liquid
Component Mole Flow							
WATER	KMOL/HR	0.85	28.36	2015.67	6.55	14783.78	14783.78
ETOH	KMOL/HR	1.32	0.21	25.98	0	29.24	29.24
CO2	KMOL/HR	15.38	1166.53	1.11	0	1.11	1.11
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	0	0	0	0	0
C5POLY	KMOL/HR	0	0	0	0	0	0
C6POLY	KMOL/HR	0	0	0	0	0	0
PROTINS	KMOL/HR	0	0	0	0	0	0
OIL	KMOL/HR	0	0	0	0	0	0
NFDS	KMOL/HR	0	0	0	0	0	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	0	0	0
Component Mass Flow							
WATER	KG/HR	15.32	510.84	36312.32	117.97	266329.8	266329.8
ETOH	KG/HR	60.8	9.52	1197.06	0	1347.1	1347.09
CO2	KG/HR	676.8	51338.82	49.02	0	49	49
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	0	0

		73CO2	74CO2	75SW	7ENZYME	85PC	86HPC
From		**ED07**	**SCRUBBER**	**SCRUBBER**		**SPLITPC**	**DUPLHPC**
To		**SCRUBBER**		**PCST**	**LIQUEFY**	**DUPLHPC**	**LIQUEFY**
C5POLY	KG/HR	0	0	0	0	0	0
C6POLY	KG/HR	0	0	0	0	0	0
PROTINS	KG/HR	0	0	0	0	0	0
OIL	KG/HR	0	0	0	0	0	0
NFDS	KG/HR	0	0	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	0	0
Component Mass Fraction							
WATER		0.02	0.01	0.97	1	0.99	0.99
ETOH		0.08	0	0.03	0	0.01	0.01
CO2		0.9	0.99	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0	0
C5POLY		0	0	0	0	0	0
C6POLY		0	0	0	0	0	0
PROTINS		0	0	0	0	0	0
OIL		0	0	0	0	0	0
NFDS		0	0	0	0	0	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0	0	0	0	0
Mole Flow	KMOL/HR	17.55	1195.09	2042.77	6.55	14814.14	14814.14
Mass Flow	KG/HR	752.91	51859.17	37558.4	117.97	267725.9	267725.9
Volume Flow	L/MIN	6853.84	469940.5	638.91	1.97	4669.89	4669.89
Temperature	C	37.78	20.33	31.94	21.11	62.02	62.02
Pressure	ATM	1.09	1.02	1.02	1	2.04	2.04
Vapor Fraction		1	1	0	0	0	0
Liquid Fraction		0	0	1	1	1	1
Solid Fraction		0	0	0	0	0	0
Molar Enthalpy	CAL/MOL	-89320.42	-93224.6	-68154.6	-68343.04	-67617.16	-67617.17
Mass Enthalpy	CAL/GM	-2081.82	-2148.35	-3706.87	-3793.67	-3741.47	-3741.47
Enthalpy Flow	CAL/SEC	-435397.1	-30947690	-38673360	-124319.1	-278247200	-278247200
Molar Entropy	CAL/MOL-K	-2.77	0.47	-38.95	-39.13	-36.86	-36.86
Mass Entropy	CAL/GM-K	-0.06	0.01	-2.12	-2.17	-2.04	-2.04
Molar Density	MOL/CC	0	0	0.05	0.06	0.05	0.05
Mass Density	GM/CC	0	0	0.98	1	0.96	0.96
Average Molecular Weight		42.91	43.39	18.39	18.02	18.07	18.07
Substream: CISOLID							
Component Mole Flow							
WATER	KMOL/HR	0	0	0	0	0	0
ETOH	KMOL/HR	0	0	0	0	0	0
CO2	KMOL/HR	0	0	0	0	0	0
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	0	0	0	0	0
C5POLY	KMOL/HR	0	0	0	0	0	0
C6POLY	KMOL/HR	0	0	0	0	0	0
PROTINS	KMOL/HR	0	0	0	0	0	0
OIL	KMOL/HR	0	0	0	0	0	0
NFDS	KMOL/HR	0	0	0	0	0	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	0	0	0

		73CO2	74CO2	75SW	7ENZYME	85PC	86HPC
From		**ED07**	**SCRUBBER**	**SCRUBBER**		**SPLITPC**	**DUPLHPC**
To		**SCRUBBER**		**PCST**	**LIQUEFY**	**DUPLHPC**	**LIQUEFY**
Component Mass Flow							
WATER	KG/HR	0	0	0	0	0	0
ETOH	KG/HR	0	0	0	0	0	0
CO2	KG/HR	0	0	0	0	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	0	0
C5POLY	KG/HR	0	0	0	0	0	0
C6POLY	KG/HR	0	0	0	0	0	0
PROTINS	KG/HR	0	0	0	0	0	0
OIL	KG/HR	0	0	0	0	0	0
NFDS	KG/HR	0	0	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	0	0
Component Mass Fraction							
WATER							
ETOH							
CO2							
GLUCOSE							
STARCH							
C5POLY							
C6POLY							
PROTINS							
OIL							
NFDS							
XYLOSE							
PROTSOL							
Mole Flow	KMOL/HR	0	0	0	0	0	0
Mass Flow	KG/HR	0	0	0	0	0	0
Volume Flow	L/MIN	0	0	0	0	0	0
Temperature	C						
Pressure	ATM	1.09		1.02	1	2.04	
Vapor Fraction							
Liquid Fraction							
Solid Fraction							
Molar Enthalpy	CAL/MOL						
Mass Enthalpy	CAL/GM						
Enthalpy Flow	CAL/SEC						
Molar Entropy	CAL/MOL-K						
Mass Entropy	CAL/GM-K						
Molar Density	MOL/CC						
Mass Density	GM/CC						
Average Molecular Weight							

		87WATER	8CIP	9AMMONIA	BEER	CO21	CO22
From					**FERMENT**	**FERMDG**	**DUPLCO2**
To		**SCRUBBER**	**LIQUEFY**	**LIQUEFY**	**FERMDG**	**DUPLCO2**	**MULTCO2**
Substream: ALL							
Mass Flow	KG/HR	35884.86	8456.32	336.46	525258.8	52779.79	52779.79
Mass Enthalpy	CAL/SEC	-37894750	-8525151	-155430.1	-455734200	-31290910	-31290910
MASSFLOW							
WATER	KG/HR	35884.86	8033.46	0	359825	922.97	922.97
ETOH	KG/HR	0	0	0	55158.88	1145.78	1145.78
CO2	KG/HR	0	0	0	51429.04	50711.04	50711.04
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	1006.35	0	0
C5POLY	KG/HR	0	0	0	7638.2	0	0
C6POLY	KG/HR	0	0	0	4406.66	0	0
PROTINS	KG/HR	0	0	0	8519.53	0	0
OIL	KG/HR	0	0	0	5875.54	0	0
NFDS	KG/HR	0	422.86	336.46	22052.03	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	9347.55	0	0
MASSFRAC							
WATER		1	0.95	0	0.69	0.02	0.02
ETOH		0	0	0	0.11	0.02	0.02
CO2		0	0	0	0.1	0.96	0.96
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0	0
C5POLY		0	0	0	0.01	0	0
C6POLY		0	0	0	0.01	0	0
PROTINS		0	0	0	0.02	0	0
OIL		0	0	0	0.01	0	0
NFDS		0	0.05	1	0.04	0	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0	0	0.02	0	0
Substream: MIXED							
Phase:		Liquid	Liquid	Liquid	Mixed	Vapor	Vapor
Component Mole Flow							
WATER	KMOL/HR	1991.94	445.93	0	19973.63	51.23	51.23
ETOH	KMOL/HR	0	0	0	1197.31	24.87	24.87
CO2	KMOL/HR	0	0	0	1168.58	1152.26	1152.26
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	0	0	0	0	0
C5POLY	KMOL/HR	0	0	0	0	0	0
C6POLY	KMOL/HR	0	0	0	0	0	0
PROTINS	KMOL/HR	0	0	0	0	0	0
OIL	KMOL/HR	0	0	0	0	0	0
NFDS	KMOL/HR	0	2.82	2.24	146.89	0	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	62.26	0	0
Component Mass Flow							
WATER	KG/HR	35884.86	8033.46	0	359825	922.97	922.97
ETOH	KG/HR	0	0	0	55158.88	1145.78	1145.78
CO2	KG/HR	0	0	0	51429.04	50711.04	50711.04
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	0	0

		87WATER	8CIP	9AMMONIA	BEER	CO21	CO22
From					FERMENT	FERMDG	DUPLCO2
To		SCRUBBER	LIQUEFY	LIQUEFY	FERMDG	DUPLCO2	MULTCO2
C5POLY	KG/HR	0	0	0	0	0	0
C6POLY	KG/HR	0	0	0	0	0	0
PROTINS	KG/HR	0	0	0	0	0	0
OIL	KG/HR	0	0	0	0	0	0
NFDS	KG/HR	0	422.86	336.46	22052.03	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	9347.55	0	0
Component Mass Fraction							
WATER		1	0.95	0	0.72	0.02	0.02
ETOH		0	0	0	0.11	0.02	0.02
CO2		0	0	0	0.1	0.96	0.96
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0	0
C5POLY		0	0	0	0	0	0
C6POLY		0	0	0	0	0	0
PROTINS		0	0	0	0	0	0
OIL		0	0	0	0	0	0
NFDS		0	0.05	1	0.04	0	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0	0	0.02	0	0
Mole Flow	KMOL/HR	1991.94	448.75	2.24	22548.67	1228.37	1228.37
Mass Flow	KG/HR	35884.86	8456.32	336.46	497812.5	52779.79	52779.79
Volume Flow	L/MIN	595.28	147.46	4.29	478689.3	471188.2	471188.2
Temperature	C	12.78	82.22	21.11	32.22	32.22	32.22
Pressure	ATM	2.04	1	1	1.09	1.09	1.09
Vapor Fraction		0	0	0	0.05	1	1
Liquid Fraction		1	1	1	0.95	0	0
Solid Fraction		0	0	0	0	0	0
Molar Enthalpy	CAL/MOL	-68486.43	-68391.41	-249672.3	-71065.07	-91704.96	-91704.96
Mass Enthalpy	CAL/GM	-3801.63	-3629.3	-1663.04	-3218.93	-2134.29	-2134.29
Enthalpy Flow	CAL/SEC	-37894750	-8525151	-155430.1	-445117400	-31290910	-31290910
Molar Entropy	CAL/MOL-K	-39.66	-35.54	-18.98	-38.17	-0.28	-0.28
Mass Entropy	CAL/GM-K	-2.2	-1.89	-0.13	-1.73	-0.01	-0.01
Molar Density	MOL/CC	0.06	0.05	0.01	0	0	0
Mass Density	GM/CC	1	0.96	1.31	0.02	0	0
Average Molecular Weight		18.02	18.84	150.13	22.08	42.97	42.97
Substream: CISOLID							
Component Mole Flow							
WATER	KMOL/HR	0	0	0	0	0	0
ETOH	KMOL/HR	0	0	0	0	0	0
CO2	KMOL/HR	0	0	0	0	0	0
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	0	0	6.21	0	0
C5POLY	KMOL/HR	0	0	0	57.81	0	0
C6POLY	KMOL/HR	0	0	0	27.18	0	0
PROTINS	KMOL/HR	0	0	0	64.49	0	0
OIL	KMOL/HR	0	0	0	44.47	0	0
NFDS	KMOL/HR	0	0	0	0	0	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	0	0	0

		87WATER	8CIP	9AMMONIA	BEER	CO21	CO22
From					**FERMENT**	**FERMDG**	**DUPLCO2**
To		**SCRUBBER**	**LIQUEFY**	**LIQUEFY**	**FERMDG**	**DUPLCO2**	**MULTCO2**
Component Mass Flow							
WATER	KG/HR	0	0	0	0	0	0
ETOH	KG/HR	0	0	0	0	0	0
CO2	KG/HR	0	0	0	0	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	1006.35	0	0
C5POLY	KG/HR	0	0	0	7638.2	0	0
C6POLY	KG/HR	0	0	0	4406.66	0	0
PROTINS	KG/HR	0	0	0	8519.53	0	0
OIL	KG/HR	0	0	0	5875.54	0	0
NFDS	KG/HR	0	0	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	0	0
Component Mass Fraction							
WATER					0		
ETOH					0		
CO2					0		
GLUCOSE					0		
STARCH					0.04		
C5POLY					0.28		
C6POLY					0.16		
PROTINS					0.31		
OIL					0.21		
NFDS					0		
XYLOSE					0		
PROTSOL					0		
Mole Flow	KMOL/HR	0	0	0	200.16	0	0
Mass Flow	KG/HR	0	0	0	27446.28	0	0
Volume Flow	L/MIN	0	0	0	299.13	0	0
Temperature	C				32.22		
Pressure	ATM	2.04	1	1	1.09	1.09	1.09
Vapor Fraction					0		
Liquid Fraction					0		
Solid Fraction					1		
Molar Enthalpy	CAL/MOL				-190952.5		
Mass Enthalpy	CAL/GM				-1392.56		
Enthalpy Flow	CAL/SEC				-10616850		
Molar Entropy	CAL/MOL-K				-637.61		
Mass Entropy	CAL/GM-K				-4.65		
Molar Density	MOL/CC				0.01		
Mass Density	GM/CC				1.53		
Average Molecular Weight					137.12		

		CO23	CO24	CO2WAT	CON1	CON6	COND
From		MULTCO2	CO2AGIT	SEPETH	COND1	COND6	ED07
To		CO2AGIT			MIXCON	MIXCON	PRESS
Substream: ALL							
Mass Flow	KG/HR	26389.9	26389.9	247.22	11473.67	175411.6	3873.28
Mass Enthalpy	CAL/SEC	-15645450	-15501320	-240467.2	-11949700	-183170300	-2650867
MASSFLOW							
WATER	KG/HR	461.48	461.48	206.02	11420.08	175336.4	1694.92
ETOH	KG/HR	572.89	572.89	0	53.58	75.26	2164.2
CO2	KG/HR	25355.52	25355.52	41.2	0	0	14.15
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	0	0
C5POLY	KG/HR	0	0	0	0	0	0
C6POLY	KG/HR	0	0	0	0	0	0
PROTINS	KG/HR	0	0	0	0	0	0
OIL	KG/HR	0	0	0	0	0	0
NFDS	KG/HR	0	0	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	0	0
MASSFRAC							
WATER		0.02	0.02	0.83	1	1	0.44
ETOH		0.02	0.02	0	0	0	0.56
CO2		0.96	0.96	0.17	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0	0
C5POLY		0	0	0	0	0	0
C6POLY		0	0	0	0	0	0
PROTINS		0	0	0	0	0	0
OIL		0	0	0	0	0	0
NFDS		0	0	0	0	0	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0	0	0	0	0
Substream: MIXED							
Phase:		Vapor	Vapor	Mixed	Liquid	Liquid	Liquid
Component Mole Flow							
WATER	KMOL/HR	25.62	25.62	11.44	633.92	9732.8	94.08
ETOH	KMOL/HR	12.44	12.44	0	1.16	1.63	46.98
CO2	KMOL/HR	576.13	576.13	0.94	0	0	0.32
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	0	0	0	0	0
C5POLY	KMOL/HR	0	0	0	0	0	0
C6POLY	KMOL/HR	0	0	0	0	0	0
PROTINS	KMOL/HR	0	0	0	0	0	0
OIL	KMOL/HR	0	0	0	0	0	0
NFDS	KMOL/HR	0	0	0	0	0	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	0	0	0
Component Mass Flow							
WATER	KG/HR	461.48	461.48	206.02	11420.08	175336.4	1694.92
ETOH	KG/HR	572.89	572.89	0	53.58	75.26	2164.2
CO2	KG/HR	25355.52	25355.52	41.2	0	0	14.15
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	0	0

		CO23	CO24	CO2WAT	CON1	CON6	COND
From		MULTCO2	CO2AGIT	SEPETH	COND1	COND6	ED07
To		CO2AGIT			MIXCON	MIXCON	PRESS
C5POLY	KG/HR	0	0	0	0	0	0
C6POLY	KG/HR	0	0	0	0	0	0
PROTINS	KG/HR	0	0	0	0	0	0
OIL	KG/HR	0	0	0	0	0	0
NFDS	KG/HR	0	0	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	0	0
Component Mass Fraction							
WATER		0.02	0.02	0.83	1	1	0.44
ETOH		0.02	0.02	0	0	0	0.56
CO2		0.96	0.96	0.17	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0	0
C5POLY		0	0	0	0	0	0
C6POLY		0	0	0	0	0	0
PROTINS		0	0	0	0	0	0
OIL		0	0	0	0	0	0
NFDS		0	0	0	0	0	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0	0	0	0	0
Mole Flow	KMOL/HR	614.18	614.18	12.37	635.08	9734.43	141.38
Mass Flow	KG/HR	26389.9	26389.9	247.22	11473.67	175411.6	3873.28
Volume Flow	L/MIN	235594.1	122589.7	334.83	198.72	3035.05	74.62
Temperature	C	32.22	121.08	37.78	55.28	55.28	37.78
Pressure	ATM	1.09	2.7	1.26	1.02	1.02	1.09
Vapor Fraction		1	1	0.08	0	0	0
Liquid Fraction		0	0	0.92	1	1	1
Solid Fraction		0	0	0	0	0	0
Molar Enthalpy	CAL/MOL	-91704.96	-90860.12	-69970.36	-67737.41	-67740.26	-67498.43
Mass Enthalpy	CAL/GM	-2134.29	-2114.63	-3501.66	-3749.36	-3759.23	-2463.84
Enthalpy Flow	CAL/SEC	-15645450	-15501320	-240467.2	-11949700	-183170300	-2650867
Molar Entropy	CAL/MOL-K	-0.28	0.34	-35.07	-37.23	-37.17	-51.94
Mass Entropy	CAL/GM-K	-0.01	0.01	-1.76	-2.06	-2.06	-1.9
Molar Density	MOL/CC	0	0	0	0.05	0.05	0.03
Mass Density	GM/CC	0	0	0.01	0.96	0.96	0.87
Average Molecular Weight		42.97	42.97	19.98	18.07	18.02	27.4
Substream: CISOLID							
Component Mole Flow							
WATER	KMOL/HR	0	0	0	0	0	0
ETOH	KMOL/HR	0	0	0	0	0	0
CO2	KMOL/HR	0	0	0	0	0	0
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	0	0	0	0	0
C5POLY	KMOL/HR	0	0	0	0	0	0
C6POLY	KMOL/HR	0	0	0	0	0	0
PROTINS	KMOL/HR	0	0	0	0	0	0
OIL	KMOL/HR	0	0	0	0	0	0
NFDS	KMOL/HR	0	0	0	0	0	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	0	0	0

		CO23	CO24	CO2WAT	CON1	CON6	COND
From		**MULTCO2**	**CO2AGIT**	**SEPETH**	**COND1**	**COND6**	**ED07**
To		**CO2AGIT**			**MIXCON**	**MIXCON**	**PRESS**
Component Mass Flow							
WATER	KG/HR	0	0	0	0	0	0
ETOH	KG/HR	0	0	0	0	0	0
CO2	KG/HR	0	0	0	0	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	0	0
C5POLY	KG/HR	0	0	0	0	0	0
C6POLY	KG/HR	0	0	0	0	0	0
PROTINS	KG/HR	0	0	0	0	0	0
OIL	KG/HR	0	0	0	0	0	0
NFDS	KG/HR	0	0	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	0	0
Component Mass Fraction							
WATER							
ETOH							
CO2							
GLUCOSE							
STARCH							
C5POLY							
C6POLY							
PROTINS							
OIL							
NFDS							
XYLOSE							
PROTSOL							
Mole Flow	KMOL/HR	0	0	0	0	0	0
Mass Flow	KG/HR	0	0	0	0	0	0
Volume Flow	L/MIN	0	0	0	0	0	0
Temperature	C						
Pressure	ATM	1.09	2.7	1.26	1.02	1.02	1.09
Vapor Fraction							
Liquid Fraction							
Solid Fraction							
Molar Enthalpy	CAL/MOL						
Mass Enthalpy	CAL/GM						
Enthalpy Flow	CAL/SEC						
Molar Entropy	CAL/MOL-K						
Mass Entropy	CAL/GM-K						
Molar Density	MOL/CC						
Mass Density	GM/CC						
Average Molecular Weight							

		COOL1	COOL2	COOL3	COOL4	DDGS	EVAP1
From		**FERMDG**	**DUPLCOOL**	**MULTCOOL**	**COOLER**	**MIXDDGS**	**PRE-EVAP**
To		**DUPLCOOL**	**MULTCOOL**	**COOLER**		**DRYDDGS**	**COND1**
Substream: ALL							
Mass Flow	KG/HR	472479	472479	4488550	4488550	108670.6	11473.67
Mass Enthalpy	CAL/SEC	-424443300	-424443300	-4.032E+09	-4.037E+09	-81334520	-10121290
MASSFLOW							
WATER	KG/HR	358902	358902	3409569	3409569	57717.72	11420.08
ETOH	KG/HR	54013.1	54013.1	513124.4	513124.4	16.66	53.58
CO2	KG/HR	718	718	6821	6821	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	1006.35	1006.35	9560.28	9560.28	984.73	0
C5POLY	KG/HR	7638.2	7638.2	72562.93	72562.93	7474.1	0
C6POLY	KG/HR	4406.66	4406.66	41863.23	41863.23	4311.98	0
PROTINS	KG/HR	8519.53	8519.53	80935.57	80935.57	8336.5	0
OIL	KG/HR	5875.54	5875.54	55817.64	55817.64	5749.31	0
NFDS	KG/HR	22052.03	22052.03	209494.3	209494.3	16911.18	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	9347.55	9347.55	88801.7	88801.7	7168.42	0
MASSFRAC							
WATER		0.76	0.76	0.76	0.76	0.53	1
ETOH		0.11	0.11	0.11	0.11	0	0
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0.01	0
C5POLY		0.02	0.02	0.02	0.02	0.07	0
C6POLY		0.01	0.01	0.01	0.01	0.04	0
PROTINS		0.02	0.02	0.02	0.02	0.08	0
OIL		0.01	0.01	0.01	0.01	0.05	0
NFDS		0.05	0.05	0.05	0.05	0.16	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0.02	0.02	0.02	0.02	0.07	0
Substream: MIXED							
Phase:		Liquid	Liquid	Liquid	Liquid	Liquid	Vapor
Component Mole Flow							
WATER	KMOL/HR	19922.4	19922.4	189262.8	189262.8	3203.87	633.92
ETOH	KMOL/HR	1172.44	1172.44	11138.17	11138.17	0.36	1.16
CO2	KMOL/HR	16.31	16.31	154.99	154.99	0	0
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	0	0	0	0	0
C5POLY	KMOL/HR	0	0	0	0	0	0
C6POLY	KMOL/HR	0	0	0	0	0	0
PROTINS	KMOL/HR	0	0	0	0	0	0
OIL	KMOL/HR	0	0	0	0	0	0
NFDS	KMOL/HR	146.89	146.89	1395.42	1395.42	112.64	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	62.26	62.26	591.5	591.5	47.75	0
Component Mass Flow							
WATER	KG/HR	358902	358902	3409569	3409569	57717.72	11420.08
ETOH	KG/HR	54013.1	54013.1	513124.4	513124.4	16.66	53.58
CO2	KG/HR	718	718	6821	6821	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	0	0

		COOL1	COOL2	COOL3	COOL4	DDGS	EVAP1
From		FERMDG	DUPLCOOL	MULTCOOL	COOLER	MIXDDGS	PRE-EVAP
To		DUPLCOOL	MULTCOOL	COOLER		DRYDDGS	COND1
C5POLY	KG/HR	0	0	0	0	0	0
C6POLY	KG/HR	0	0	0	0	0	0
PROTINS	KG/HR	0	0	0	0	0	0
OIL	KG/HR	0	0	0	0	0	0
NFDS	KG/HR	22052.03	22052.03	209494.3	209494.3	16911.18	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	9347.55	9347.55	88801.7	88801.7	7168.42	0
Component Mass Fraction							
WATER		0.81	0.81	0.81	0.81	0.71	1
ETOH		0.12	0.12	0.12	0.12	0	0
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0	0
C5POLY		0	0	0	0	0	0
C6POLY		0	0	0	0	0	0
PROTINS		0	0	0	0	0	0
OIL		0	0	0	0	0	0
NFDS		0.05	0.05	0.05	0.05	0.21	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0.02	0.02	0.02	0.02	0.09	0
Mole Flow	KMOL/HR	21320.3	21320.3	202542.9	202542.9	3364.62	635.08
Mass Flow	KG/HR	445032.7	445032.7	4227810	4227810	81813.97	11473.67
Volume Flow	L/MIN	7501.06	7501.06	71260.12	70916.48	1276.83	732154.4
Temperature	C	32.22	32.22	32.22	27.56	82.65	77.39
Pressure	ATM	1.09	1.09	1.09	2.09	1.02	0.42
Vapor Fraction		0	0	0	0	0	1
Liquid Fraction		1	1	1	1	1	0
Solid Fraction		0	0	0	0	0	0
Molar Enthalpy	CAL/MOL	-69875.9	-69875.9	-69875.9	-69961.33	-75932.67	-57372.98
Mass Enthalpy	CAL/GM	-3347.56	-3347.56	-3347.56	-3351.66	-3122.75	-3175.68
Enthalpy Flow	CAL/SEC	-413826500	-413826500	-3.931E+09	-3.936E+09	-70968010	-10121290
Molar Entropy	CAL/MOL-K	-40.35	-40.35	-40.35	-40.64	-34.43	-7.6
Mass Entropy	CAL/GM-K	-1.93	-1.93	-1.93	-1.95	-1.42	-0.42
Molar Density	MOL/CC	0.05	0.05	0.05	0.05	0.04	0
Mass Density	GM/CC	0.99	0.99	0.99	0.99	1.07	0
Average Molecular Weight		20.87	20.87	20.87	20.87	24.32	18.07
Substream: CISOLID							
Component Mole Flow							
WATER	KMOL/HR	0	0	0	0	0	0
ETOH	KMOL/HR	0	0	0	0	0	0
CO2	KMOL/HR	0	0	0	0	0	0
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	6.21	6.21	58.96	58.96	6.07	0
C5POLY	KMOL/HR	57.81	57.81	549.24	549.24	56.57	0
C6POLY	KMOL/HR	27.18	27.18	258.19	258.19	26.59	0
PROTINS	KMOL/HR	64.49	64.49	612.61	612.61	63.1	0
OIL	KMOL/HR	44.47	44.47	422.49	422.49	43.52	0
NFDS	KMOL/HR	0	0	0	0	0	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	0	0	0

		COOL1	COOL2	COOL3	COOL4	DDGS	EVAP1
From		FERMDG	DUPLCOOL	MULTCOOL	COOLER	MIXDDGS	PRE-EVAP
To		DUPLCOOL	MULTCOOL	COOLER		DRYDDGS	COND1
Component Mass Flow							
WATER	KG/HR	0	0	0	0	0	0
ETOH	KG/HR	0	0	0	0	0	0
CO2	KG/HR	0	0	0	0	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	1006.35	1006.35	9560.28	9560.28	984.73	0
C5POLY	KG/HR	7638.2	7638.2	72562.93	72562.93	7474.1	0
C6POLY	KG/HR	4406.66	4406.66	41863.23	41863.23	4311.98	0
PROTINS	KG/HR	8519.53	8519.53	80935.57	80935.57	8336.5	0
OIL	KG/HR	5875.54	5875.54	55817.64	55817.64	5749.31	0
NFDS	KG/HR	0	0	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	0	0
Component Mass Fraction							
WATER		0	0	0	0	0	
ETOH		0	0	0	0	0	
CO2		0	0	0	0	0	
GLUCOSE		0	0	0	0	0	
STARCH		0.04	0.04	0.04	0.04	0.04	
C5POLY		0.28	0.28	0.28	0.28	0.28	
C6POLY		0.16	0.16	0.16	0.16	0.16	
PROTINS		0.31	0.31	0.31	0.31	0.31	
OIL		0.21	0.21	0.21	0.21	0.21	
NFDS		0	0	0	0	0	
XYLOSE		0	0	0	0	0	
PROTSOL		0	0	0	0	0	
Mole Flow	KMOL/HR	200.16	200.16	1901.5	1901.5	195.86	0
Mass Flow	KG/HR	27446.28	27446.28	260739.6	260739.6	26856.62	0
Volume Flow	L/MIN	299.13	299.13	2841.76	2841.76	292.71	0
Temperature	C	32.22	32.22	32.22	27.56	82.65	
Pressure	ATM	1.09	1.09	1.09	2.09	1.02	0.42
Vapor Fraction		0	0	0	0	0	
Liquid Fraction		0	0	0	0	0	
Solid Fraction		1	1	1	1	1	
Molar Enthalpy	CAL/MOL	-190952.5	-190952.5	-190952.5	-190972.4	-190543.6	
Mass Enthalpy	CAL/GM	-1392.56	-1392.56	-1392.56	-1392.71	-1389.58	
Enthalpy Flow	CAL/SEC	-10616850	-10616850	-100860100	-100870600	-10366510	
Molar Entropy	CAL/MOL-K	-637.61	-637.61	-637.61	-637.67	-636.38	
Mass Entropy	CAL/GM-K	-4.65	-4.65	-4.65	-4.65	-4.64	
Molar Density	MOL/CC	0.01	0.01	0.01	0.01	0.01	
Mass Density	GM/CC	1.53	1.53	1.53	1.53	1.53	
Average Molecular Weight		137.12	137.12	137.12	137.12	137.12	

		EVAP6	EXTRAPC	HPC	HPC2	MASH	PC
From		**EVAP6**	**SPLITPC**	**DUPLHPC**	**EM01**	**EM01DUTY**	**PCST**
To		**COND6**		**EM01**		**MIXBS**	**SPLITPC**
Substream: ALL							
Mass Flow	KG/HR	175411.6	99.64	267725.9	267725.9	445935.1	267825.6
Mass Enthalpy	CAL/SEC	-154761800	-103558.4	-278247200	-273904800	-368567800	-278350800
MASSFLOW							
WATER	KG/HR	175336.4	99.12	266329.8	266329.8	299845.9	266429
ETOH	KG/HR	75.26	0.5	1347.1	1347.1	1347.09	1347.6
CO2	KG/HR	0	0.02	49	49	49	49.02
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	100612.9	0
C5POLY	KG/HR	0	0	0	0	7474.1	0
C6POLY	KG/HR	0	0	0	0	4311.98	0
PROTINS	KG/HR	0	0	0	0	8336.5	0
OIL	KG/HR	0	0	0	0	5749.31	0
NFDS	KG/HR	0	0	0	0	12458.97	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	5749.31	0
MASSFRAC							
WATER		1	0.99	0.99	0.99	0.67	0.99
ETOH		0	0.01	0.01	0.01	0	0.01
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0.23	0
C5POLY		0	0	0	0	0.02	0
C6POLY		0	0	0	0	0.01	0
PROTINS		0	0	0	0	0.02	0
OIL		0	0	0	0	0.01	0
NFDS		0	0	0	0	0.03	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0	0	0	0.01	0
Substream: MIXED							
Phase:		Vapor	Liquid	Liquid	Mixed	Liquid	Liquid
Component Mole Flow							
WATER	KMOL/HR	9732.8	5.5	14783.78	14783.78	16644.23	14789.28
ETOH	KMOL/HR	1.63	0.01	29.24	29.24	29.24	29.25
CO2	KMOL/HR	0	0	1.11	1.11	1.11	1.11
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	0	0	0	0	0
C5POLY	KMOL/HR	0	0	0	0	0	0
C6POLY	KMOL/HR	0	0	0	0	0	0
PROTINS	KMOL/HR	0	0	0	0	0	0
OIL	KMOL/HR	0	0	0	0	0	0
NFDS	KMOL/HR	0	0	0	0	82.99	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	0	38.3	0
Component Mass Flow							
WATER	KG/HR	175336.4	99.12	266329.8	266329.8	299845.9	266429
ETOH	KG/HR	75.26	0.5	1347.1	1347.1	1347.09	1347.6
CO2	KG/HR	0	0.02	49	49	49	49.02
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	0	0

		EVAP6	EXTRAPC	HPC	HPC2	MASH	PC
From		**EVAP6**	**SPLITPC**	**DUPLHPC**	**EM01**	**EM01DUTY**	**PCST**
To		**COND6**		**EM01**		**MIXBS**	**SPLITPC**
C5POLY	KG/HR	0	0	0	0	0	0
C6POLY	KG/HR	0	0	0	0	0	0
PROTINS	KG/HR	0	0	0	0	0	0
OIL	KG/HR	0	0	0	0	0	0
NFDS	KG/HR	0	0	0	0	12458.97	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	5749.31	0
Component Mass Fraction							
WATER		1	0.99	0.99	0.99	0.94	0.99
ETOH		0	0.01	0.01	0.01	0	0.01
CO2		0	0	0	0	0	0
GLUCOSE		0	0	0	0	0	0
STARCH		0	0	0	0	0	0
C5POLY		0	0	0	0	0	0
C6POLY		0	0	0	0	0	0
PROTINS		0	0	0	0	0	0
OIL		0	0	0	0	0	0
NFDS		0	0	0	0	0.04	0
XYLOSE		0	0	0	0	0	0
PROTSOL		0	0	0	0	0.02	0
Mole Flow	KMOL/HR	9734.43	5.51	14814.14	14814.14	16795.87	14819.65
Mass Flow	KG/HR	175411.6	99.64	267725.9	267725.9	319450.3	267825.6
Volume Flow	L/MIN	6706185	1.74	4669.89	6725.91	5593.88	4671.63
Temperature	C	94.89	62.02	62.02	117.53	87.78	62.02
Pressure	ATM	0.73	2.04	2.04	2.04	3.4	2.04
Vapor Fraction		1	0	0	0	0	0
Liquid Fraction		0	1	1	1	1	1
Solid Fraction		0	0	0	0	0	0
Molar Enthalpy	CAL/MOL	-57234.22	-67617.16	-67617.16	-66561.92	-68457.96	-67617.16
Mass Enthalpy	CAL/GM	-3176.2	-3741.47	-3741.47	-3683.09	-3599.34	-3741.47
Enthalpy Flow	CAL/SEC	-154761800	-103558.4	-278247200	-273904800	-319392000	-278350800
Molar Entropy	CAL/MOL-K	-8.28	-36.86	-36.86	-33.99	-35.28	-36.86
Mass Entropy	CAL/GM-K	-0.46	-2.04	-2.04	-1.88	-1.85	-2.04
Molar Density	MOL/CC	0	0.05	0.05	0.04	0.05	0.05
Mass Density	GM/CC	0	0.96	0.96	0.66	0.95	0.96
Average Molecular Weight		18.02	18.07	18.07	18.07	19.02	18.07
Substream: CISOLID							
Component Mole Flow							
WATER	KMOL/HR	0	0	0	0	0	0
ETOH	KMOL/HR	0	0	0	0	0	0
CO2	KMOL/HR	0	0	0	0	0	0
GLUCOSE	KMOL/HR	0	0	0	0	0	0
STARCH	KMOL/HR	0	0	0	0	620.53	0
C5POLY	KMOL/HR	0	0	0	0	56.57	0
C6POLY	KMOL/HR	0	0	0	0	26.59	0
PROTINS	KMOL/HR	0	0	0	0	63.1	0
OIL	KMOL/HR	0	0	0	0	43.52	0
NFDS	KMOL/HR	0	0	0	0	0	0
XYLOSE	KMOL/HR	0	0	0	0	0	0
PROTSOL	KMOL/HR	0	0	0	0	0	0

		EVAP6	EXTRAPC	HPC	HPC2	MASH	PC
From		**EVAP6**	**SPLITPC**	**DUPLHPC**	**EM01**	**EM01DUTY**	**PCST**
To		**COND6**		**EM01**		**MIXBS**	**SPLITPC**
Component Mass Flow							
WATER	KG/HR	0	0	0	0	0	0
ETOH	KG/HR	0	0	0	0	0	0
CO2	KG/HR	0	0	0	0	0	0
GLUCOSE	KG/HR	0	0	0	0	0	0
STARCH	KG/HR	0	0	0	0	100612.9	0
C5POLY	KG/HR	0	0	0	0	7474.1	0
C6POLY	KG/HR	0	0	0	0	4311.98	0
PROTINS	KG/HR	0	0	0	0	8336.5	0
OIL	KG/HR	0	0	0	0	5749.31	0
NFDS	KG/HR	0	0	0	0	0	0
XYLOSE	KG/HR	0	0	0	0	0	0
PROTSOL	KG/HR	0	0	0	0	0	0
Component Mass Fraction							
WATER						0	
ETOH						0	
CO2						0	
GLUCOSE						0	
STARCH						0.8	
C5POLY						0.06	
C6POLY						0.03	
PROTINS						0.07	
OIL						0.05	
NFDS						0	
XYLOSE						0	
PROTSOL						0	
Mole Flow	KMOL/HR	0	0	0	0	810.31	0
Mass Flow	KG/HR	0	0	0	0	126484.8	0
Volume Flow	L/MIN	0	0	0	0	1378.24	0
Temperature	C					87.78	
Pressure	ATM	0.73	2.04	2.04	2.04	3.4	2.04
Vapor Fraction						0	
Liquid Fraction						0	
Solid Fraction						1	
Molar Enthalpy	CAL/MOL					-218475.2	
Mass Enthalpy	CAL/GM					-1399.64	
Enthalpy Flow	CAL/SEC					-49175860	
Molar Entropy	CAL/MOL-K					-732.52	
Mass Entropy	CAL/GM-K					-4.69	
Molar Density	MOL/CC					0.01	
Mass Density	GM/CC					1.53	
Average Molecular Weight						156.09	

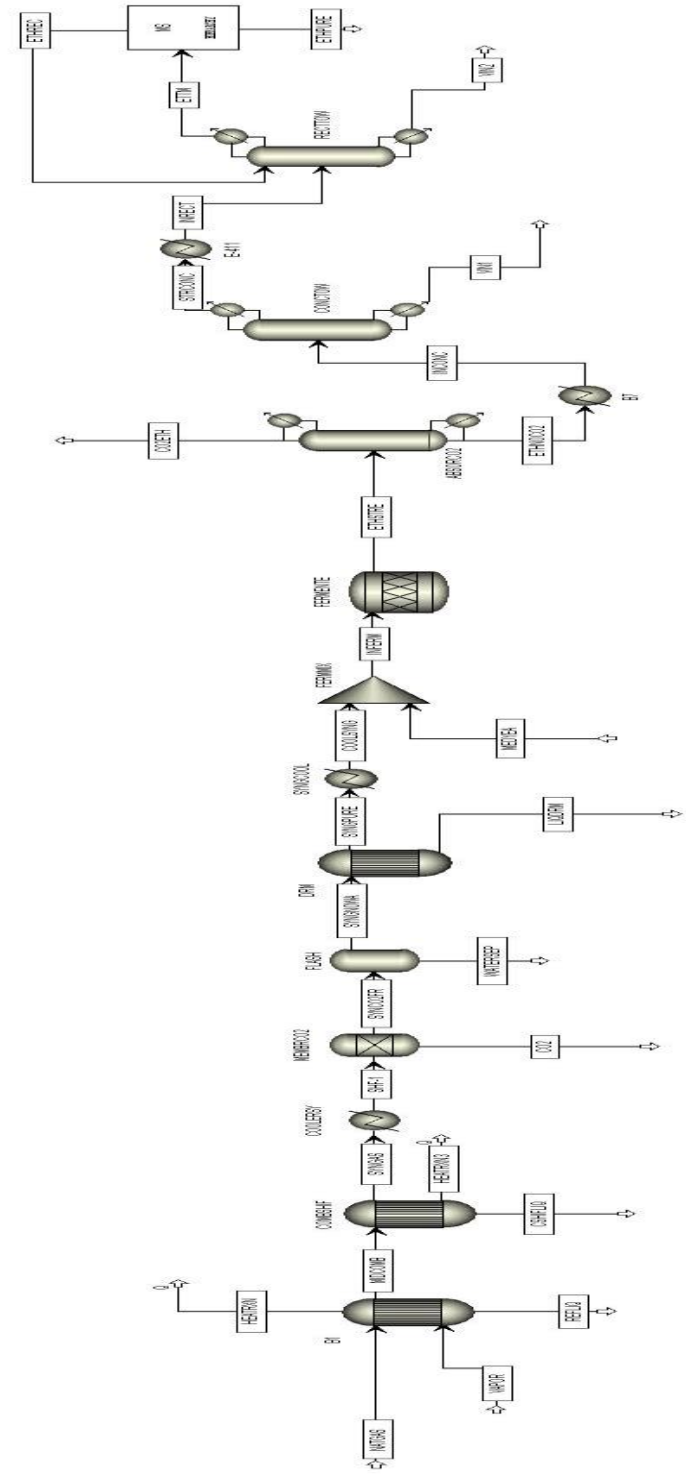
		PCOND	PURETH	YEAST
From		**PRESS**	**SEPETH**	
To		**BEERCOL**		**FERMENT**
Substream: ALL				
Mass Flow	KG/HR	3873.28	53757.14	31.79
Mass Enthalpy	CAL/SEC	-2650805	-21393800	-33467.95
MASSFLOW				
WATER	KG/HR	1694.92	0	31.79
ETOH	KG/HR	2164.2	53757.14	0
CO2	KG/HR	14.15	0	0
GLUCOSE	KG/HR	0	0	0
STARCH	KG/HR	0	0	0
C5POLY	KG/HR	0	0	0
C6POLY	KG/HR	0	0	0
PROTINS	KG/HR	0	0	0
OIL	KG/HR	0	0	0
NFDS	KG/HR	0	0	0
XYLOSE	KG/HR	0	0	0
PROTSOL	KG/HR	0	0	0
MASSFRAC				
WATER		0.44	0	1
ETOH		0.56	1	0
CO2		0	0	0
GLUCOSE		0	0	0
STARCH		0	0	0
C5POLY		0	0	0
C6POLY		0	0	0
PROTINS		0	0	0
OIL		0	0	0
NFDS		0	0	0
XYLOSE		0	0	0
PROTSOL		0	0	0
Substream: MIXED				
Phase:		Liquid	Liquid	Liquid
Component Mole Flow				
WATER	KMOL/HR	94.08	0	1.76
ETOH	KMOL/HR	46.98	1166.88	0
CO2	KMOL/HR	0.32	0	0
GLUCOSE	KMOL/HR	0	0	0
STARCH	KMOL/HR	0	0	0
C5POLY	KMOL/HR	0	0	0
C6POLY	KMOL/HR	0	0	0
PROTINS	KMOL/HR	0	0	0
OIL	KMOL/HR	0	0	0
NFDS	KMOL/HR	0	0	0
XYLOSE	KMOL/HR	0	0	0
PROTSOL	KMOL/HR	0	0	0
Component Mass Flow				
WATER	KG/HR	1694.92	0	31.79
ETOH	KG/HR	2164.2	53757.14	0
CO2	KG/HR	14.15	0	0
GLUCOSE	KG/HR	0	0	0
STARCH	KG/HR	0	0	0

		PCOND	PURETH	YEAST
From		PRESS	SEPETH	
To		BEERCOL		FERMENT
C5POLY	KG/HR	0	0	0
C6POLY	KG/HR	0	0	0
PROTINS	KG/HR	0	0	0
OIL	KG/HR	0	0	0
NFDS	KG/HR	0	0	0
XYLOSE	KG/HR	0	0	0
PROTSOL	KG/HR	0	0	0
Component Mass Fraction				
WATER		0.44	0	1
ETOH		0.56	1	0
CO2		0	0	0
GLUCOSE		0	0	0
STARCH		0	0	0
C5POLY		0	0	0
C6POLY		0	0	0
PROTINS		0	0	0
OIL		0	0	0
NFDS		0	0	0
XYLOSE		0	0	0
PROTSOL		0	0	0
Mole Flow	KMOL/HR	141.38	1166.88	1.76
Mass Flow	KG/HR	3873.28	53757.14	31.79
Volume Flow	L/MIN	74.63	1164.86	0.53
Temperature	C	37.84	37.78	25
Pressure	ATM	1.7	1.26	1
Vapor Fraction		0	0	0
Liquid Fraction		1	1	1
Solid Fraction		0	0	0
Molar Enthalpy	CAL/MOL	-67496.84	-66002.9	-68275.68
Mass Enthalpy	CAL/GM	-2463.78	-1432.7	-3789.93
Enthalpy Flow	CAL/SEC	-2650805	-21393800	-33467.95
Molar Entropy	CAL/MOL-K	-51.94	-81.37	-38.9
Mass Entropy	CAL/GM-K	-1.9	-1.77	-2.16
Molar Density	MOL/CC	0.03	0.02	0.06
Mass Density	GM/CC	0.86	0.77	0.99
Average Molecular Weight		27.4	46.07	18.02
Substream: CISOLID				
Component Mole Flow				
WATER	KMOL/HR	0	0	0
ETOH	KMOL/HR	0	0	0
CO2	KMOL/HR	0	0	0
GLUCOSE	KMOL/HR	0	0	0
STARCH	KMOL/HR	0	0	0
C5POLY	KMOL/HR	0	0	0
C6POLY	KMOL/HR	0	0	0
PROTINS	KMOL/HR	0	0	0
OIL	KMOL/HR	0	0	0
NFDS	KMOL/HR	0	0	0
XYLOSE	KMOL/HR	0	0	0
PROTSOL	KMOL/HR	0	0	0

		PCOND	PURETH	YEAST
From		**PRESS**	**SEPETH**	
To		**BEERCOL**		**FERMENT**
Component Mass Flow				
WATER	KG/HR	0	0	0
ETOH	KG/HR	0	0	0
CO2	KG/HR	0	0	0
GLUCOSE	KG/HR	0	0	0
STARCH	KG/HR	0	0	0
C5POLY	KG/HR	0	0	0
C6POLY	KG/HR	0	0	0
PROTINS	KG/HR	0	0	0
OIL	KG/HR	0	0	0
NFDS	KG/HR	0	0	0
XYLOSE	KG/HR	0	0	0
PROTSOL	KG/HR	0	0	0
Component Mass Fraction				
WATER				
ETOH				
CO2				
GLUCOSE				
STARCH				
C5POLY				
C6POLY				
PROTINS				
OIL				
NFDS				
XYLOSE				
PROTSOL				
Mole Flow	KMOL/HR	0	0	0
Mass Flow	KG/HR	0	0	0
Volume Flow	L/MIN	0	0	0
Temperature	C			
Pressure	ATM	1.7	1.26	1
Vapor Fraction				
Liquid Fraction				
Solid Fraction				
Molar Enthalpy	CAL/MOL			
Mass Enthalpy	CAL/GM			
Enthalpy Flow	CAL/SEC			
Molar Entropy	CAL/MOL-K			
Mass Entropy	CAL/GM-K			
Molar Density	MOL/CC			
Mass Density	GM/CC			
Average Molecular Weight				

APPENDIX C

SHALE GAS SIMULATION WORKFLOW



APPENDIX D

SHALE GAS SIMULATION CURRENTS

CURRENTS		CO2	CO2ETH	COOLSYNG	CSHIFLIQ	ETHNOCO2	ETHPURE
From		MEMBRCO2	ABSORCO2	SYNGCOOL	COMBSHIF	ABSORCO2	$C-3
To				FERMMIX		B7	
Substream: MIXED							
Phase:		Vapor	Vapor	Vapor	Missing	Liquid	Liquid
Component Mole Flow							
METHANE	KMOL/HR	0.1206742	0.9232523	0.9232523	0	0	0
WATER	KMOL/HR	14.67455	0.2093978	4.614509	0	6.77053	0.0273492
CO	KMOL/HR	0.0832156	0.2725242	27.25242	0	0	0
CO2	KMOL/HR	62.32454	6.890191	0.0143593	0	0	0
H2	KMOL/HR	0.1299323	299.5355	331.2326	0	0	0
N2	KMOL/HR	0	0	0	0	0	0
O2	KMOL/HR	0	0	0	0	0	0
ETHANOL	KMOL/HR	0	0.2770337	0	0	8.957424	7.464492
A.ACETIC	KMOL/HR	0	0.8175725	0	0	0	0
Mole Flow	KMOL/HR	77.33291	308.9254	364.0371	0	15.72795	7.491841
Mass Flow	KG/HR	3011.785	995.1408	1529.651	0	534.6329	344.3747
Volume Flow	CUM/HR	1311.551	7865.582	9268.768	0	0.6483353	0.431135
Temperature	C	136.85	37	37		37	25
Pressure	ATM	1.974	1	1	10	1	1
Vapor Fraction		1	1	1		0	0
Liquid Fraction		0	0	0		1	1
Solid Fraction		0	0	0		0	0
Molar Enthalpy	J/KMOL	-3.59E+08	-1.03E+07	-1.12E+07		-2.78E+08	-2.78E+08
Mass Enthalpy	J/KG	-9.22E+06	-3.19E+06	-2.66E+06		-8.18E+06	-6.05E+06
Enthalpy Flow	WATT	-7.71E+06	-8.81E+05	-1.13E+06		-1.21E+06	-5.79E+05
Molar Entropy	J/KMOL-K	4703.895	1675.563	9972.731		-2.57E+05	-3.48E+05
Mass Entropy	J/KG-K	120.7808	520.1515	2373.38		-7571.271	-7575.373
Molar Density	KMOL/CUM	0.0589629	0.0392756	0.0392756		24.25898	17.37702
Mass Density	KG/CUM	2.296354	0.1265184	0.1650329		824.6241	798.763
Average Molecular Weight		38.94571	3.221298	4.20191		33.99253	45.96663
Phase: All							
MOLEFRAC							
METHANE		1.56E-03	2.99E-03	2.54E-03		0	0
WATER		0.1897581	6.78E-04	0.0126759		0.4304775	3.65E-03
CO		1.08E-03	8.82E-04	0.0748616		0	0
CO2		0.8059252	0.0223037	3.94E-05		0	0
H2		1.68E-03	0.9696044	0.9098868		0	0
N2		0	0	0		0	0
O2		0	0	0		0	0
ETHANOL		0	8.97E-04	0		0.5695225	0.9963495
A.ACETIC		0	2.65E-03	0		0	0
MASSFRAC							
METHANE		6.43E-04	0.0148838	9.68E-03		0	0
WATER		0.0877772	3.79E-03	0.0543468		0.2281434	1.43E-03
CO		7.74E-04	7.67E-03	0.499036		0	0
CO2		0.9107191	0.3047166	4.13E-04		0	0
H2		8.70E-05	0.606776	0.4365211		0	0
N2		0	0	0		0	0
O2		0	0	0		0	0
ETHANOL		0	0.012825	0		0.7718566	0.9985693
A.ACETIC		0	0.049337	0		0	0
MASSFLOW							

CURRENTS		CO2	CO2ETH	COOLSYNG	CSHIFLIQ	ETHNOCO2	ETHPURE
From		MEMBRCO2	ABSORCO2	SYNGCOOL	COMBSHIF	ABSORCO2	$C-3
To				FERMMIX		B7	
METHANE	KG/HR	1.935947	14.81151	14.81151		0	0
WATER	KG/HR	264.3661	3.772361	83.13167		121.973	0.492705
CO	KG/HR	2.330903	7.633511	763.3511		0	0
CO2	KG/HR	2742.89	303.2359	0.631952		0	0
H2	KG/HR	0.261928	603.8275	667.7252		0	0
N2	KG/HR	0	0	0		0	0
O2	KG/HR	0	0	0		0	0
ETHANOL	KG/HR	0	12.76268	0		412.6599	343.882
A.ACETIC	KG/HR	0	49.09732	0		0	0
MOLEFLOW							
METHANE	KMOL/HR	0.1206742	0.9232523	0.9232523		0	0
WATER	KMOL/HR	14.67455	0.2093978	4.614509		6.77053	0.0273492
CO	KMOL/HR	0.0832156	0.2725242	27.25242		0	0
CO2	KMOL/HR	62.32454	6.890191	0.0143593		0	0
H2	KMOL/HR	0.1299323	299.5355	331.2326		0	0
N2	KMOL/HR	0	0	0		0	0
O2	KMOL/HR	0	0	0		0	0
ETHANOL	KMOL/HR	0	0.2770337	0		8.957424	7.464492
A.ACETIC	KMOL/HR	0	0.8175725	0		0	0

CURRENTS		ETHREC	ETHSTRE	ETTM	INCONC	INFERM	INRECT
From		$C-2	FERMENTE	RECTTOW	B7	FERMMIX	E-411
To		RECTTOW	ABSORCO2	$C-1	CONCTOW	FERMENTE	RECTTOW
Substream: MIXED							
Phase:		Vapor	Vapor	Vapor	Liquid	Vapor	Liquid
Component Mole Flow							
METHANE	KMOL/HR	0	0.9232523	0	0	0.9232523	0
WATER	KMOL/HR	8.635344	6.979928	9.116428	6.77053	4.621301	5.984132
CO	KMOL/HR	0	0.2725242	0	0	27.25242	0
CO2	KMOL/HR	0	6.890191	0	0	0.0143593	0
H2	KMOL/HR	0	299.5355	0	0	331.2326	0
N2	KMOL/HR	0	0	0	0	0	0
O2	KMOL/HR	0	0	0	0	0	0
ETHANOL	KMOL/HR	28.36505	9.234458	37.32246	8.957424	0	8.957424
A.ACETIC	KMOL/HR	0	0.8175725	0	0	0	0
Mole Flow	KMOL/HR	37.00039	324.6534	46.43889	15.72795	364.0439	14.94156
Mass Flow	KG/HR	1462.319	1529.774	1883.645	534.6329	1529.774	520.4657
Volume Flow	CUM/HR	1111.459	8264.794	1298.126	0.6812559	9268.049	0.6676421
Temperature	C	98.88889	37	74.52514	70	36.97017	71.11111
Pressure	ATM	1	1	1	1	1	1.77
Vapor Fraction		1	1	1	0	1	0
Liquid Fraction		0	0	0	1	0	1
Solid Fraction		0	0	0	0	0	0
Molar Enthalpy	J/KMOL	-2.32E+08	-2.13E+07	-2.33E+08	-2.74E+08	-1.12E+07	-2.74E+08
Mass Enthalpy	J/KG	-5.87E+06	-4.51E+06	-5.75E+06	-8.06E+06	-2.67E+06	-7.86E+06
Enthalpy Flow	WATT	-2.39E+06	-1.92E+06	-3.01E+06	-1.20E+06	-1.13E+06	-1.14E+06
Molar Entropy	J/KMOL-K	-1.65E+05	-3612.496	-1.76E+05	-2.45E+05	9969.633	-2.50E+05
Mass Entropy	J/KG-K	-4171.042	-766.6553	-4345.1	-7216.845	2372.497	-7186.181
Molar Density	KMOL/CUM	0.0332899	0.0392814	0.0357737	23.0867	0.0392794	22.37959
Mass Density	KG/CUM	1.315675	0.1850952	1.451049	784.7754	0.1650589	779.558
Average Molecular Weight		39.52171	4.712022	40.5618	33.99253	4.202168	34.83344
Phase: All							
MOLEFRAC							
METHANE		0	2.84E-03	0	0	2.54E-03	0
WATER		0.2333852	0.0214996	0.1963102	0.4304775	0.0126943	0.4005026
CO		0	8.39E-04	0	0	0.0748602	0
CO2		0	0.0212232	0	0	3.94E-05	0
H2		0	0.9226316	0	0	0.9098699	0
N2		0	0	0	0	0	0
O2		0	0	0	0	0	0
ETHANOL		0.7666148	0.028444	0.8036898	0.5695225	0	0.5994974
A.ACETIC		0	2.52E-03	0	0	0	0
MASSFRAC							
METHANE		0	9.68E-03	0	0	9.68E-03	0
WATER		0.1063846	0.0821986	0.08719	0.2281434	0.0544224	0.2071334
CO		0	4.99E-03	0	0	0.4989961	0
CO2		0	0.1982227	0	0	4.13E-04	0
H2		0	0.3947169	0	0	0.4364862	0
N2		0	0	0	0	0	0
O2		0	0	0	0	0	0
ETHANOL		0.8936154	0.2780951	0.91281	0.7718566	0	0.7928666
A.ACETIC		0	0.0320945	0	0	0	0
MASSFLOW							

CURRENTS		ETHREC	ETHSTRE	ETTM	INCONC	INFERM	INRECT
From		$C-2	FERMENTE	RECTTOW	B7	FERMMIX	E-411
To		RECTTOW	ABSORCO2	$C-1	CONCTOW	FERMENTE	RECTTOW
METHANE	KG/HR	0	14.81151	0	0	14.81151	0
WATER	KG/HR	155.5681	125.7454	164.235	121.973	83.25404	107.8058
CO	KG/HR	0	7.633511	0	0	763.3511	0
CO2	KG/HR	0	303.2359	0	0	0.631952	0
H2	KG/HR	0	603.8275	0	0	667.7252	0
N2	KG/HR	0	0	0	0	0	0
O2	KG/HR	0	0	0	0	0	0
ETHANOL	KG/HR	1306.75	425.4226	1719.41	412.6599	0	412.6599
A.ACETIC	KG/HR	0	49.09732	0	0	0	0
MOLEFLOW							
METHANE	KMOL/HR	0	0.9232523	0	0	0.9232523	0
WATER	KMOL/HR	8.635344	6.979928	9.116428	6.77053	4.621301	5.984132
CO	KMOL/HR	0	0.2725242	0	0	27.25242	0
CO2	KMOL/HR	0	6.890191	0	0	0.0143593	0
H2	KMOL/HR	0	299.5355	0	0	331.2326	0
N2	KMOL/HR	0	0	0	0	0	0
O2	KMOL/HR	0	0	0	0	0	0
ETHANOL	KMOL/HR	28.36505	9.234458	37.32246	8.957424	0	8.957424
A.ACETIC	KMOL/HR	0	0.8175725	0	0	0	0

CURRENTS		LIQDRM	MEDYEA	MIDCOMB	NATGAS	REFLIQ	SHF-1
From		DRM		B1		B1	COOLERSY
To			FERMMIX	COMBSHIF	B1		MEMBRCO2
Substream: MIXED							
Phase:		Missing	Liquid	Vapor	Vapor	Missing	Vapor
Component Mole Flow							
METHANE	KMOL/HR	0	0	4.309793	90.71847	0	4.309793
WATER	KMOL/HR	0	6.79E-03	149.4593	0	0	83.85457
CO	KMOL/HR	0	0	86.40868	0	0	20.8039
CO2	KMOL/HR	0	0	0	0	0	65.60478
H2	KMOL/HR	0	0	259.226	0	0	324.8308
N2	KMOL/HR	0	0	0	0	0	0
O2	KMOL/HR	0	0	0	0	0	0
ETHANOL	KMOL/HR	0	0	0	0	0	0
A.ACETIC	KMOL/HR	0	0	0	0	0	0
Mole Flow	KMOL/HR	0	6.79E-03	499.4039	90.71847	0	499.4039
Mass Flow	KG/HR	0	0.12237	5704.603	1455.375	0	5704.603
Volume Flow	CUM/HR	0	1.23E-04	4731.171	141.5767	0	8509.847
Temperature	C		25	879.4444	371.1111		136.85
Pressure	ATM	1	1	10	34.02298	10	1.974
Vapor Fraction			0	1	1		1
Liquid Fraction			1	0	0		0
Solid Fraction			0	0	0		0
Molar Enthalpy	J/KMOL		-2.88E+08	-6.42E+07	-5.91E+07		-9.40E+07
Mass Enthalpy	J/KG		-1.60E+07	-5.62E+06	-3.68E+06		-8.23E+06
Enthalpy Flow	WATT		-542.9099	-8.91E+06	-1.49E+06		-1.30E+07
Molar Entropy	J/KMOL-K		-1.68E+05	34475.8	-76478.55		8736.194
Mass Entropy	J/KG-K		-9319.868	3018.149	-4767.169		764.8015
Molar Density	KMOL/CUM		55.173	0.1055561	0.6407728		0.0586854
Mass Density	KG/CUM		993.957	1.205749	10.27976		0.6703532
Average Molecular Weight			18.01528	11.42283	16.04276		11.42283
Phase: All							
MOLEFRAC							
METHANE			0	8.63E-03	1		8.63E-03
WATER			1	0.2992755	0		0.1679093
CO			0	0.1730237	0		0.0416574
CO2			0	0	0		0.1313662
H2			0	0.519071	0		0.6504371
N2			0	0	0		0
O2			0	0	0		0
ETHANOL			0	0	0		0
A.ACETIC			0	0	0		0
MASSFRAC							
METHANE			0	0.0121202	1		0.0121202
WATER			1	0.4719964	0		0.2648148
CO			0	0.4242787	0		0.1021501
CO2			0	0	0		0.5061269
H2			0	0.0916047	0		0.114788
N2			0	0	0		0
O2			0	0	0		0
ETHANOL			0	0	0		0
A.ACETIC			0	0	0		0
MASSFLOW							

CURRENTS		LIQDRM	MEDYEA	MIDCOMB	NATGAS	REFLIQ	SHF-1
From		DRM		B1		B1	COOLERSY
To			FERMMIX	COMBSHIF	B1		MEMBRCO2
METHANE	KG/HR		0	69.14097	1455.375		69.14097
WATER	KG/HR		0.12237	2692.552	0		1510.664
CO	KG/HR		0	2420.342	0		582.7256
CO2	KG/HR		0	0	0		2887.253
H2	KG/HR		0	522.5686	0		654.8199
N2	KG/HR		0	0	0		0
O2	KG/HR		0	0	0		0
ETHANOL	KG/HR		0	0	0		0
A.ACETIC	KG/HR		0	0	0		0
MOLEFLOW							
METHANE	KMOL/HR		0	4.309793	90.71847		4.309793
WATER	KMOL/HR		6.79E-03	149.4593	0		83.85457
CO	KMOL/HR		0	86.40868	0		20.8039
CO2	KMOL/HR		0	0	0		65.60478
H2	KMOL/HR		0	259.226	0		324.8308
N2	KMOL/HR		0	0	0		0
O2	KMOL/HR		0	0	0		0
ETHANOL	KMOL/HR		0	0	0		0
A.ACETIC	KMOL/HR		0	0	0		0

CURRENTS		STRCONC	SYNCO2FR	SYNGAS	SYNGNOWA	SYNGPURE	VAPOR
From		CONCTOW	MEMBRCO2	COMBSHIF	FLASH	DRM	
To		E-411	FLASH	COOLERSY	DRM	SYNGCOOL	B1
Substream: MIXED							
Phase:		Vapor	Vapor	Vapor	Vapor	Vapor	Vapor
Component Mole Flow							
METHANE	KMOL/HR	0	4.189119	4.309793	4.189117	0.9232523	0
WATER	KMOL/HR	5.984132	69.18002	83.85457	4.614509	4.614509	235.868
CO	KMOL/HR	0	20.72069	20.8039	20.72069	27.25242	0
CO2	KMOL/HR	0	3.280239	65.60478	3.280224	0.0143593	0
H2	KMOL/HR	0	324.7009	324.8308	324.7009	331.2326	0
N2	KMOL/HR	0	0	0	0	0	0
O2	KMOL/HR	0	0	0	0	0	0
ETHANOL	KMOL/HR	8.957424	0	0	0	0	0
A.ACETIC	KMOL/HR	0	0	0	0	0	0
Mole Flow	KMOL/HR	14.94156	422.071	499.4039	357.5054	364.0371	235.868
Mass Flow	KG/HR	520.4657	2692.818	5704.603	1529.651	1529.651	4249.229
Volume Flow	CUM/HR	416.6483	7194.969	2764.273	4432.332	26083.07	257.3337
Temperature	C	72.77721	136.85	400	24.85	599.85	246.1111
Pressure	ATM	1	1.974	10	1.974	1	34.02298
Vapor Fraction		1	1	1	1	1	1
Liquid Fraction		0	0	0	0	0	0
Solid Fraction		0	0	0	0	0	0
Molar Enthalpy	J/KMOL	-2.35E+08	-4.55E+07	-8.54E+07	-1.40E+07	5.45E+06	-2.36E+08
Mass Enthalpy	J/KG	-6.75E+06	-7.13E+06	-7.48E+06	-3.28E+06	1.30E+06	-1.31E+07
Enthalpy Flow	WATT	-9.76E+05	-5.34E+06	-1.19E+07	-1.39E+06	5.51E+05	-1.55E+07
Molar Entropy	J/KMOL-K	-1.39E+05	6295.289	11436.93	1364.823	40503.08	-56834.55
Mass Entropy	J/KG-K	-3996.599	986.7205	1001.235	318.9822	9639.207	-3154.797
Molar Density	KMOL/CUM	0.0358613	0.0586619	0.1806637	0.0806585	0.0139568	0.9165842
Mass Density	KG/CUM	1.249173	0.374264	2.06369	0.3451121	0.0586453	16.51252
Average Molecular Weight		34.83344	6.380012	11.42283	4.27868	4.20191	18.01528
Phase: All							
MOLEFRAC							
METHANE		0	9.93E-03	8.63E-03	0.0117176	2.54E-03	0
WATER		0.4005026	0.1639061	0.1679093	0.0129075	0.0126759	1
CO		0	0.0490929	0.0416574	0.057959	0.0748616	0
CO2		0	7.77E-03	0.1313662	9.18E-03	3.94E-05	0
H2		0	0.769304	0.6504371	0.9082404	0.9098868	0
N2		0	0	0	0	0	0
O2		0	0	0	0	0	0
ETHANOL		0.5994974	0	0	0	0	0
A.ACETIC		0	0	0	0	0	0
MASSFRAC							
METHANE		0	0.0249571	0.0121202	0.0439348	9.68E-03	0
WATER		0.2071334	0.4628228	0.2648148	0.0543468	0.0543468	1
CO		0	0.2155343	0.1021501	0.3794294	0.499036	0
CO2		0	0.0536102	0.5061269	0.0943757	4.13E-04	0
H2		0	0.2430755	0.114788	0.4279132	0.4365211	0
N2		0	0	0	0	0	0
O2		0	0	0	0	0	0
ETHANOL		0.7928666	0	0	0	0	0
A.ACETIC		0	0	0	0	0	0
MASSFLOW							

CURRENTS		STRCONC	SYNCO2FR	SYNGAS	SYNGNOWA	SYNGPURE	VAPOR
From		CONCTOW	MEMBRCO2	COMBSHIF	FLASH	DRM	
To		E-411	FLASH	COOLERSY	DRM	SYNGCOOL	B1
METHANE	KG/HR	0	67.20502	69.14097	67.205	14.81151	0
WATER	KG/HR	107.8058	1246.297	1510.664	83.13167	83.13167	4249.229
CO	KG/HR	0	580.3947	582.7256	580.3947	763.3511	0
CO2	KG/HR	0	144.3627	2887.253	144.362	0.631952	0
H2	KG/HR	0	654.558	654.8199	654.558	667.7252	0
N2	KG/HR	0	0	0	0	0	0
O2	KG/HR	0	0	0	0	0	0
ETHANOL	KG/HR	412.6599	0	0	0	0	0
A.ACETIC	KG/HR	0	0	0	0	0	0
MOLEFLOW							
METHANE	KMOL/HR	0	4.189119	4.309793	4.189117	0.9232523	0
WATER	KMOL/HR	5.984132	69.18002	83.85457	4.614509	4.614509	235.868
CO	KMOL/HR	0	20.72069	20.8039	20.72069	27.25242	0
CO2	KMOL/HR	0	3.280239	65.60478	3.280224	0.0143593	0
H2	KMOL/HR	0	324.7009	324.8308	324.7009	331.2326	0
N2	KMOL/HR	0	0	0	0	0	0
O2	KMOL/HR	0	0	0	0	0	0
ETHANOL	KMOL/HR	8.957424	0	0	0	0	0
A.ACETIC	KMOL/HR	0	0	0	0	0	0

CURRENTS		VIN1	VIN2	WATERSEP
From		CONCTOW	RECTTOW	FLASH
To				
Substream: MIXED				
Phase:		Liquid	Liquid	Liquid
Component Mole Flow				
METHANE	KMOL/HR	0	0	1.34E-06
WATER	KMOL/HR	0.7863977	5.503062	64.56551
CO	KMOL/HR	0	0	5.71E-07
CO2	KMOL/HR	0	0	1.45E-05
H2	KMOL/HR	0	0	1.85E-05
N2	KMOL/HR	0	0	0
O2	KMOL/HR	0	0	0
ETHANOL	KMOL/HR	1.25E-08	7.92E-13	0
A.ACETIC	KMOL/HR	0	0	0
Mole Flow	KMOL/HR	0.7863977	5.503062	64.56555
Mass Flow	KG/HR	14.16718	99.13919	1163.166
Volume Flow	CUM/HR	0.0154616	0.1081978	1.170068
Temperature	C	101.8985	101.8986	24.85
Pressure	ATM	1	1	1.974
Vapor Fraction		0	0	0
Liquid Fraction		1	1	1
Solid Fraction		0	0	0
Molar Enthalpy	J/KMOL	-2.81E+08	-2.81E+08	-2.88E+08
Mass Enthalpy	J/KG	-1.56E+07	-1.56E+07	-1.60E+07
Enthalpy Flow	WATT	-61478.51	-4.30E+05	-5.16E+06
Molar Entropy	J/KMOL-K	-1.49E+05	-1.49E+05	-1.68E+05
Mass Entropy	J/KG-K	-8276.922	-8276.92	-9322.212
Molar Density	KMOL/CUM	50.86114	50.86114	55.181
Mass Density	KG/CUM	916.2778	916.2777	994.1012
Average Molecular Weight		18.01528	18.01528	18.01528
Phase: All				
MOLEFRAC				
METHANE		0	0	2.08E-08
WATER		1	1	0.9999995
CO		0	0	8.84E-09
CO2		0	0	2.25E-07
H2		0	0	2.86E-07
N2		0	0	0
O2		0	0	0
ETHANOL		1.59E-08	1.44E-13	0
A.ACETIC		0	0	0
MASSFRAC				
METHANE		0	0	1.85E-08
WATER		1	1	0.9999994
CO		0	0	1.37E-08
CO2		0	0	5.50E-07
H2		0	0	3.21E-08
N2		0	0	0
O2		0	0	0
ETHANOL		4.07E-08	3.68E-13	0
A.ACETIC		0	0	0
MASSFLOW				

CURRENTS		VIN1	VIN2	WATERSEP
From		CONCTOW	RECTTOW	FLASH
To				
METHANE	KG/HR	0	0	2.16E-05
WATER	KG/HR	14.16717	99.13919	1163.166
CO	KG/HR	0	0	1.60E-05
CO2	KG/HR	0	0	6.39E-04
H2	KG/HR	0	0	3.73E-05
N2	KG/HR	0	0	0
O2	KG/HR	0	0	0
ETHANOL	KG/HR	5.77E-07	3.65E-11	0
A.ACETIC	KG/HR	0	0	0
MOLEFLOW				
METHANE	KMOL/HR	0	0	1.34E-06
WATER	KMOL/HR	0.7863977	5.503062	64.56551
CO	KMOL/HR	0	0	5.71E-07
CO2	KMOL/HR	0	0	1.45E-05
H2	KMOL/HR	0	0	1.85E-05
N2	KMOL/HR	0	0	0
O2	KMOL/HR	0	0	0
ETHANOL	KMOL/HR	1.25E-08	7.92E-13	0
A.ACETIC	KMOL/HR	0	0	0